Computational and Technology Research

Program Mission

The mission of the Computational and Technology Research (CTR) program, which consists of two distinct activities, is

- to foster and support fundamental research in advanced computing research — applied mathematics, computer science, and networking — and to operate supercomputer, networking, and related facilities to enable the analysis, modeling, simulation, and prediction of complex phenomena important to the Department of Energy, and
- to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the Nation's energy sector.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goals

- Maintain world leadership in areas of advanced computing research relevant to the complex problems of the Department of Energy.
- Integrate the results of advanced computing research into the natural sciences and engineering.
- Provide world-class supercomputer and networking facilities for scientists working on problems that are important for the Department.
- Integrate and disseminate the results of high-risk research in the natural sciences and engineering to the private sector through the Laboratory Technology Research subprogram.

Program Objectives

- *Foster and support fundamental, peer-reviewed research.* — Foster research to create new fundamental knowledge in areas of advanced computing research important to the Department.
- *Apply advanced computing knowledge to complex problems of importance to DOE.* — Promote the transfer of the results of advanced computing research to contribute to DOE missions in areas such as the improved use of fossil fuels including understanding the combustion process; the atmospheric and environmental impacts of energy production and use including global climate modeling and subsurface transport; and future energy sources including fusion energy.
- *Plan, fabricate, assemble, and operate premier supercomputer and networking facilities.* — Serve researchers at national laboratories, universities, and industry, thus enabling both new understanding

through analysis, modeling, and simulation of complex problems and effective integration of geographically distributed teams through national collaboratories.

- *Transfer results of fundamental research to the private sector.* — Provide tangible results of research and development activities through cost-shared partnerships with industry.

Performance Measures

The Computational and Technology Research program measures performance in various ways, depending on the objective. However, performance measures fall into four broad categories: (1) peer review; (2) indicators or metrics (i.e., things that can be counted); (3) customer evaluation and stakeholder input; and (4) qualitative assessments, which might include historical retrospectives and annual program highlights. The key process is peer review of all research activities. Facility performance measures include achievement of performance specifications, operating time, throughput, user satisfaction, and effective utilization of resources as determined by reports from external review panels, user steering committees, and internal Office of Science (SC) program manager committees. In addition, CTR supercomputer and network facilities have periodic external performance reviews. The Energy Science Network (ESnet) operations and management were reviewed in this manner in FY 1998.

In FY 2000, (1) facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget to meet user and overall SC program requirements; (2) the operating time lost at scientific facilities due to unscheduled NERSC/ESnet downtime will be less than 10 percent of the total scheduled possible operating time, on average; (3) all new and continuing research projects will undergo regular peer review and merit evaluation based on the principles set down in 10 CFR 605 for grants or in cooperative agreements supported by the Office of Science; (4) work performed by investigators supported by CTR will continue to be recognized as outstanding through the receipt of major prizes and awards; and (5) initiate 7 Laboratory Technology Research projects that address the Department's top priorities for science and technology, through cost-shared research partnerships with industry.

Significant Accomplishments and Program Shifts

The CTR program builds on decades of leadership in advanced computing. Some of the pioneering accomplishments of this program are:

Mathematical, Information, and Computational Sciences

- **Remote, interactive access to supercomputers**. At the National Magnetic Fusion Energy Computing Center [the predecessor to the National Energy Research Scientific Computing Center (NERSC)], DOE pioneered the concept of remote, interactive access to supercomputers. Before this time, scientists using supercomputers had to travel to the location of the computer to make use of it. In addition, users were only able to use these computers by submitting jobs and waiting for hours or days to see the output. The Mathematical, Information, and Computational Sciences (MICS) subprogram developed the first interactive operating system for supercomputers, Cray Time Sharing System (CTSS), as well as a nationwide network to allow remote users to have effective access to the computers. This operating system revolutionized access to supercomputers by enabling users to see their jobs as they executed. When the National Science Foundation (NSF) initiated its Supercomputer Centers program in the 1970's, the CTSS operating system was adopted by the San Diego Supercomputing Center and the National Center for Supercomputing Applications to enable users to access NSF's first CRAY machines.

- **Numerical Linear Algebra Libraries**. Today's high performance computations rely on high performance, efficient libraries of numerical linear algebra software. These libraries, which are the core of numerical efforts in the solution of differential and integral equations — LINPACK, EISPAC, LAPACK, SCALAPACK — are the direct result of decades of DOE funding and basic research in this area. These libraries are used by thousands of researchers worldwide and are a critical part of the world's scientific computing infrastructure.

- **High Performance Parallel Interface (HiPPI)**. In order to develop a standard interface between supercomputers and other devices, such as disk arrays and archival tape systems, and visualization computers, DOE laboratories developed the high performance network interface (HiPPI) and led a consortium of vendors to make it the industry standard for the highest bandwidth interconnects between computers and peripheral devices. Many research issues in high speed signaling, data parallelism and high speed protocol design needed to be understood to enable this advance.

- **Parallel Virtual Machine (PVM) and Message Passing Interface (MPI).** DOE researchers developed PVM and MPI to enable scientists to make effective use of networks of workstations and massively parallel computers. Both of these software packages have become standards in the industry and are implemented by virtually all of the high performance computer manufacturers in the world. Both of these developments were enabled by over a decade of basic research in message passing and distributed computing supported by DOE along with many experiments to apply these techniques to real scientific problems.

- **Slow Start Algorithm for the Transmission Control Protocol (TCP)**. Transmission Control Protocol (TCP) part of TCP/IP (Internet Protocol) is responsible for ensuring that packets arrive at their destination. In 1987, as DOE and the other Federal agencies were interconnecting their networks to form the core of the Internet, critical parts of the infrastructure began to fail. There was concern that this represented a fundamental flaw in the TCP/IP architecture; however, a researcher at LBNL applied ideas from fluid flow research to understand the problem and develop a solution. This new TCP algorithm was incorporated in virtually every commercial version of Internet software within 6 months and enabled the Internet to scale from a small research network to today's worldwide infrastructure.

Building on this long history of accomplishments, principal investigators of the Computational and Technology Research program this year received recognition through numerous prizes, awards, and honors. A sample of the significant accomplishments produced by the program this year is given below.

- **1998 Gordon Bell Prize for Best Performance of a Supercomputing Application.** An international team of scientists including those from the Department's Oak Ridge and Lawrence Berkeley National Laboratories won the 1998 Gordon Bell prize for best performance of a supercomputing application for simulation of magnetism metal alloys. The team won the award for their modeling of 1,024 atoms of a metallic magnet. The calculation submitted by the team to the Gordon Bell Prize judges performed at 657 Gigaflops performance level (657 billion calculations per second); however, the team subsequently was able to raise the performance of their application to more than one teraflop (one trillion calculations per second.) In addition to supporting the winning entry, the CTR program partially supported the two other finalists.

- **1998 Fernbach Award**. Dr. Phillip Colella, a mathematician at DOE's Lawrence Berkeley National Laboratory, received the 1998 Sidney Fernbach Award at the SC98 conference in Orlando. Colella received the award for his "outstanding contribution in the application of high performance computers using innovative approaches." The Fernbach Award, created in memory of a computer scientist at DOE's Lawrence Livermore National Laboratory, is presented by the IEEE (Institute of Electrical and Electronics Engineers) Computer Society. Dr. Colella's research has focused on problems in Computational Fluid Dynamics and advanced techniques for the generation of the grids that form the basis for many scientific computations. His research has been applied to problems in the simulation of combustion devices as well as national security applications.

- **Simulation of Instabilities in Fluid Layers**. Many important physical systems can be described as layered fluids. For example, layers of oil float on salt water in geological structures. Even structures with layers of metal behave like layered fluids under high pressure and temperature. These types of systems develop very complex, unstable structures at the boundary between fluids. Computation of the characteristics of these boundaries is especially difficult, because their locations must be tracked accurately as part of the calculation. In addition, the most common formulations of the problem require many more grid points than are practical on even the largest computers. Applied mathematicians at the State University of New York, Stony Brook, in collaboration with physicists at Los Alamos National Laboratory (LANL) have discovered and implemented clever numerical schemes capable of following surfaces that can evolve into complicated shapes over time. They have used these new techniques to simulate this type of fluid instability under conditions where experiments are not possible, thus allowing design of devices for Defense Program's Advanced Strategic Computing Initiative and fusion energy applications. Modeling and simulation are absolutely vital since experimental data will never be available for conditions of importance to the designers.

- **Research in Optimization Impacts U.S. Industry**. Applied mathematicians at Rice University, working with engineers at Boeing, developed a software package for improving the manufacture of airplane components. The software combines new approaches to the optimization of systems having hundreds of thousands of parameters with research in the theory of control systems to enable engineers to optimize manufacturing processes. Previous design schemes for Boeing's production processes were based on simple "rules of thumb" that failed often in practice, and standard optimization packages were easily overwhelmed by the sheer size of the problems. This necessitated a complete rethinking of design and optimization strategies in order to accommodate industrial-size problems. The Rice researchers developed novel techniques in nonlinear optimization theory to correctly identify the underlying problems and provide feasible solutions. Boeing is using the software on its production line to lower costs and improve quality.

- **Law for Turbulent Stress Proved to be Invalid.** To design systems such as gas turbines, airplanes, or combustion devices where flow of gasses over physical structures is important, it is critical to be able to accurately describe the turbulent stress generated by the flow of the gas over the structure. Since the turn of the century, the standard methodology for calculating this was a simple mathematical model called the “law of the wall.” This model, which is found in every engineering textbook, is based on relatively crude approximations that have been accepted without serious thought since the turn of the century. Mathematicians at Lawrence Berkeley National Laboratory (LBNL) have recently developed a rigorous mathematical basis for calculating turbulent wall effects and demonstrated that the “law of the wall” is not valid in general. They showed by careful mathematical analysis that the correct description of turbulent effects on solid objects requires a family of “scaling laws” rather than a single “law of the wall.” This is difficult research since it must blend hard mathematical analysis with the proper physical insights from the fluid dynamics of turbulent flows. The discovery will have profound consequences in the engineering and design of airplanes, gas turbines, and other systems where controlling turbulence is critical to performance. The mathematical predictions of the Berkeley group have been verified recently by experiments at Princeton.

- **R&D 100 Award to Sandia Researchers.** Researchers at Sandia National Laboratories were awarded an R&D 100 award in FY 1998 for the Aztec software package. Aztec is a collection of very high performance software routines that run on the highest performance computers in the nation to solve important linear algebra problems such as solving systems of millions of linear equations. This type of linear algebra is at the core solving ordinary and partial differential equations on computers as well as many other types of scientific computations. Aztec grew out of the successful research programs at Sandia in numerical linear algebra and parallel programming techniques.

- **Advanced Computing Software Tools Enable Rapid Application Development.** One of the major challenges in modern high performance computing is to develop tools that enable scientists to quickly create computer software to solve scientific problems. Otherwise, chemists, materials scientists, and others would spend their entire effort creating software for computers that would be obsolete just as the applications were ready. The speed of change in the underlying computer architectures and the complexity of these computers and their operating systems makes this a major area of research. The Parallel Object-Oriented Methods and Applications (POOMA) Framework effort at LANL is one promising research approach to developing effective tools to help scientists in the disciplines develop software. In an early test with POOMA, a post-doc with no parallel programming experience developed computer software to solve a three dimensional fluid turbulence problem (including the tools to visualize the results while the program was running) in only six weeks rather than the 6-9 months required in similar efforts. POOMA is used extensively by two of the scientific applications pilots — the computational accelerator physics and numerical tokamak turbulence projects.

- **New Scientific Application Enabled By Interfacing Two Software Packages.** One research challenge facing advanced computing is to enable software developed by different teams to work together on massively parallel computers. Recently researchers at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL) have demonstrated that it is possible for well-designed components developed at different laboratories to be easily used together by providing each with a common interface. The latest generation of ordinary differential equation solvers for systems, whose behavior combines fine scale and large scale features, developed at LLNL has been interfaced with a large family of parallel algebraic solvers developed at ANL. This coupled software system has enabled several new applications. One of these is a collaboration of researchers at Louisiana Tech University and Oak Ridge National Laboratory

(ORNL) to develop a code for fully three-dimensional simulations of the dynamics of micro-structural interactions in materials. This code would not have been possible before the researchers had access to the coupled ANL-LLNL system.

- **Significant Speedups Achieved For Laue Crystallographic Analysis.** Advances in numerics coupled with work to enable software to run in parallel on many processors has enabled researchers in the “Supercomputer Solution of Massive Crystallographic and Microtomographic Structural Problems” scientific application pilot project to dramatically reduce the time required to analyze the data from Laue diffraction experiments. A typical illustration comes from progress made on a scientific applications project—diffraction patterns and intensities produced by x-rays passing through a crystal lattice are used to deduce information about molecular structures. The Laue diffraction technique is the most important tool in time-resolved crystallography, where structure data are captured rapidly to image the structure of a molecule at various stages of a reaction. Improved optimization and numerical techniques have been applied to the code that performs the complicated task of analyzing Laue diffraction data to obtain the structure of the molecules. The dramatic improvements in time-to-solution that have been made will significantly enhance experimental capabilities because runtimes are reduced from hours to minutes. These results are expected to be especially important for the 30 percent of users of DOE light sources who are involved in discovering protein structures.

- **ESnet Demonstrates Priority Service For Internet Traffic.** Scientists at two national laboratories successfully selected marked Internet traffic for priority service over unmarked traffic in a cross-country demonstration. This demonstration is a key milestone in the development of a broad set of capabilities called “differentiated services,” which are required for the Internet to be able to give different levels of service on demand to network customers. The demonstration of such capabilities for production-mode scientific research between Lawrence Berkeley National Laboratory and Argonne National Laboratory across the ESnet paves the way for more reliable and constant connectivity via priority bandwidth on the Internet. Achieving this improved level of service is essential to the work of the Department, which is pioneering the use of various technologies to allow scientists at more than 30 DOE national labs to share access to some of the Nation's most advanced research facilities. The complex interactions between software on computers, network hardware such as routers, and telecommunications equipment operated by commercial carriers make this a difficult research problem. In addition, all of these components must be capable of efficiently scaling up to operate across the worldwide Internet which processes tens of billions of packets a month.

- **Collaboratory Tool Attracts Users.** The electronic notebook collaboratory tool project has been so well received that over eighty groups across the country have adopted the prototype electronic notebook. Some are DOE projects, but many are from outside the Department including pharmaceuticals, chemical processing and medicine. The electronic notebook is valuable to researchers because: it can be shared by a group of researchers; it can be accessed remotely; it cannot be misplaced, lost, or accidentally destroyed (if backed up); it is easy to incorporate computer files, plots, etc.; notarization and authentication are possible; it can easily be searched for information; it can include multimedia; and it can include hyperlinks to other information. In order to enable these capabilities, the electronic notebook project has had to overcome a number of challenges including the development of new technologies for describing types of data such as experimental protocols and experimental devices, which are not well treated by traditional techniques.

Laboratory Technology Research

- In FY 1999, the SC single-purpose laboratories (Fermi National Accelerator Laboratory, Thomas Jefferson National Accelerator Facility, Princeton Plasma Physics Laboratory, and Stanford Linear Accelerator Center) and Ames Laboratory were reinstated into the Laboratory Technology Research (LTR) subprogram, thus restoring the subprogram to its original participants. LTR now provides coverage to more regions of the country where small businesses, in particular, can take advantage of the resources at SC laboratories. LTR capabilities have been enhanced for cost-shared partnerships in fusion energy sciences, high energy physics, nuclear physics, materials sciences, chemical sciences, structural biology, and other disciplines.
- The LTR subprogram received two R&D-100 awards in 1997 and three R&D-100 awards in 1998. The 1998 awards were given to:
  - Oak Ridge National Laboratory, in collaboration with the Society of Exploration Geophysicists, for "Advanced Computational Tools for 3-D Seismic Analysis." This research was cosponsored by DOE's Office of Fossil Energy.
  - Argonne National Laboratory in collaboration with Front Edge Technology of Baldwin Park, CA, Stirling Motors of Ann Arbor, MI, and Diesel Technology of Wyoming, MI, for "Near-Frictionless Carbon Coatings."
  - Argonne National Laboratory, in collaboration with Commonwealth Edison of Chicago, IL, for "Combined Expert System/Neural Network for Process Fault Diagnostics."

Advanced Energy Projects

- The Advanced Energy Projects subprogram will be terminated in FY 2000.

Scientific Facilities Utilization

The CTR program request includes $27,500,000 in FY 2000 to support the NERSC Center. This investment will provide research time for about 3,500 scientists in universities, federal agencies, and U.S. companies. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will enable NERSC to maintain its role as the Nation's largest, premier unclassified computing center, which is a critical element in the success of many SC research programs. Research communities that benefit from NERSC include structural biology; superconductor technology; medical research and technology development; materials, chemical, and plasma sciences; high energy and nuclear physics; and environmental and atmospheric research.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $46,000 and $47,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Scientific Simulation Initiative

The CTR program also leads DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs. The SSI is a significant component of the broader President's Information Technology Research Initiative (ITRI) which responds to the recommendations of the President's Information Technology Advisory Committee (PITAC). The SSI couples research in advanced scientific applications in the programs of the Office of Science (SC) with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between CTR and the other program offices in SC. The overview of the integrated program is given here; however, the specific contributions of the other programs (Basic Energy Sciences and Biological and Environmental Research) are included in their budgets. This initiative will build on and benefit from the demonstrated capabilities brought about by the Department's Accelerated Strategic Computing Initiative (ASCI) that have made it possible to obtain computational capabilities 100 times faster than currently in common use. The mission of this proposed effort is to develop further and to employ the emerging generation of very high performance computers as major tools for scientific enquiry. These resources will revolutionize our approach to solving complex problems in energy, environment, fundamental research, and technology development as well as stimulate our national system of innovation. The goal of the SSI is to:

> *"Revolutionize our ability to solve scientific problems of extraordinary complexity and to apply these resources to scientific problems relevant to the Department's mission through the exploitation of the emerging power of exceptional computational capabilities."*

As has been discussed earlier in this budget, scientific research has long been characterized as the interplay of theory and experimentation. Over the last half century the emergence of computers for solving complex mathematical problems and for analyzing large sets of data has introduced a third activity to complement both theory and experimentation. Defined as simulation and modeling, but also encompassing a broad range of data analyses, the application of computational resources to complex scientific problems has made increasingly important contributions to scientific discovery and understanding as those resources have grown more powerful. The SSI builds on DOE's 50 year history of transforming advances in information technology into tools for scientific discovery to accelerate this process through a partnership with DOE laboratories, the academic community and industry.

This program began with workshops focused on the scientific opportunities that could result from access to multi-teraflop computing. All of the programs in the Office of Science made convincing cases that access to computing at this level would open new areas of research and enable solutions to new classes of problems. These workshops culminated in a workshop on advanced scientific and engineering computing jointly sponsored by DOE and the National Science Foundation at the National Academy of Sciences in July, 1998. This workshop validated the opportunity for scientific discovery and advanced engineering afforded by terascale computing. Throughout this document, the term teraflop is used in discussing the computational resources under consideration. One teraflop is one trillion (10^{12}) floating point operations per second. For comparison, desktop personal computers are generally capable of one hundred thousand (10^{5}) floating point operations per second. Current commercially available supercomputers are capable of nearly half teraflop performance.

Based on the input from these workshops, a plan for the SSI was developed to realize the goals of the SSI. It is a balanced plan of research which includes advanced computing and communications facilities, such as terascale computers and very high performance networks, computer science and enabling technology research to make these facilities useful, and investments in scientific disciplines to enable development of the advanced applications that will be required. The strategy for SSI applications has two components. The first was a selection of two mission critical application areas: global systems and combustion systems. In both of these cases, the initial SSI planning workshops identified significant opportunities for advanced computation to dramatically advance the state of the art with important impact on the nation's ability to respond effectively to issues such as the effect of greenhouse gasses on global climate and development of internal combustion engines able to meet societal goals for efficiency and pollution control. These two initial applications play a significant role in defining the requirements for computer and communications facilities as well as the computer science and enabling technology which will be required. These two applications will also play an important role in testing, integrating, and debugging both hardware and software components. The second component of the SSI applications strategy is an open, peer reviewed competition among basic science disciplines to select a small number for initial inclusion in the initiative and access to SSI computer and communications facilities.

The Scientific Simulation Initiative Builds on ASCI

One reason the Department is prepared to undertake this initiative at this time is that the proposed effort builds upon the DOE Defense Program (DP) Accelerated Strategic Computing Initiative (ASCI) which was launched in 1996 with a focus on multi-teraflop scale computing to meet the imposing challenges posed by Science Based Stockpile Stewardship.

Meeting the goals set for ASCI requires computers with capabilities exceeding those available today by a factor of one thousand and the ASCI program is following an aggressive hardware and software technology plan that will achieve the development and use of 100 teraflop computers by 2004. As a result of the ASCI effort, much more powerful computer systems, designed for full simulation of all scientific aspects of nuclear stockpile stewardship, have been developed. ASCI continues to develop the computational infrastructure needed to make effective use of these systems, including large-scale scientific data storage capabilities, computational grids for high-speed communication, software development systems for massively parallel computer systems, high-performance visualization systems, etc. These advances, although focused on DOE's stockpile stewardship responsibility, presage the development of a comprehensive simulation capability for a whole range of scientific problems.

A Critical Element in the President's Initiative in Information Technology

Although the SSI is focused on revolutionary uses of computing as a tool for science, many of the investments in computer science and enabling technology will contribute to and benefit from the broader ITRI initiative. PITAC recommended significant increases in support for basic research in: Software, Scalable Information Infrastructure, High End Computing, and Socio-Economic and Workforce Impacts, as well as support of research projects of broader scope and visionary "Expeditions to the 21st century" to explore new ways that computing could benefit our world.

The SSI Computer Science and Enabling Technology (CSET) program has four components: Algorithms, Models, Methods and Libraries; Problem Solving Environments and Tools; Distributed Computing and Collaboration Technology; and Visualization and Data Management. The underlying strategy in all of these areas is based on taking advantage of the most recent work in software components and extending it to enable it to function at very high performance. In addition, the realities of the hardware platforms that will be available at SSI performance levels requires that the components be fault tolerant and that techniques be developed to enable the assembly of components into reliable fault tolerant assemblies. Thus, with respect to the PITAC recommendation on Software development, we expect SSI to be a significant program for fundamental research in software development methods and component technologies and to begin the development of a national repository of software components.

In addition, challenges facing SSI in the area of data management and visualization will require significant new research in the areas of human computer interfaces and interaction to enable researchers to navigate and extract scientific knowledge from petabyte-scale data archives resulting from SSI scale simulations and the coming generation of large experimental facilities. Both the SSI planning workshops as well as the ASCI Visualization Corridors workshops identified this as a critical area that would perhaps be an "Expedition to the 21st Century."

However, there are areas of software research included in the PITAC report that SSI will not cover, particularly software for systems such as air traffic control.

With regard to the PITAC recommendation on a Scalable Information Infrastructure, SSI will have a more modest impact because the problem for The SSI is primarily providing very high performance access for a modest number of people rather than providing access to billions of users worldwide.

With regard to the PITAC recommendation on High End Computing, SSI will have a major impact on R&D to improve the performance of high end computers, acquiring high end systems to support scientific research and moving towards petaop (1000 teraflop) systems by 2010. However, while SSI is a part of the solution to the problem of access to high end computing for science and engineering research and will develop many of the technologies needed to make this possible, the computing systems proposed are scaled to support a modest number of focused scientific projects, which will be collaborative efforts of large teams of disciplinary scientists, computer and computational scientists and mathematicians.

With regard to the PITAC recommendation on Socio-Economic and Workforce Impacts, The SSI will increase research funding in relevant areas of IT and will develop strategies to retrain existing scientists and IT workers as well as train new undergraduate and graduate students in these disciplines.

In addition to the research contributions that SSI will make to the broader ITRI, SSI facilities will provide crucial testbeds for testing many of the ideas that emerge from basic research in information technology.

As stated at the outset the SSI is an integrated initiative from the Office of Science. The descriptions of the various components, corresponding to the goals are included in the budgets of the responsible offices. The SSI has five principal objectives:

- **Revolutionize scientific research by the application of teraflop computational resources.** Whereas the scientific accomplishments of this century have resulted in seeking and understanding the fundamental laws that govern our physical universe, the science of the coming century will be characterized by synthesis of this knowledge into predictive capabilities for understanding and solving a wide range of scientific problems, many with practical consequences. In this endeavor, the computer will be a primary instrument of scientific discovery. Many areas of scientific inquiry critical to the Department's mission will be advanced dramatically with access to teraflop scale computing including but not limited to materials sciences, structural genomics, high energy and nuclear physics, subsurface flow, and fusion energy research.

- **Discover, develop and deploy crosscutting computer science and applied mathematics technology.** The practical and intellectual challenges to making effective use of terascale computers require the development of a terascale technology base in software, networking, data management and visualization, communications, and operating environments to enable scientists to make effective use of the simulation infrastructure.

- **Establish a national terascale distributed scientific simulation infrastructure.** This network of terascale computers, ultra-high speed communications, science centers, and support centers in academia, the national laboratories, and industry will provide the advanced computing testbeds which enable the accomplishment of the first three objectives.

- **Understand, model, and predict the effects on the earth's global environment of atmospheric greenhouse gas emissions, with an emphasis on carbon dioxide.** Through the use of teraflop scale computers, accelerate progress in general circulation model development and application to reduce substantially the uncertainties in decade-to-century model-based projections of global environmental change and to increase the utility of such projections to the broad research community. Current models of global systems cannot presently achieve regional specification in global environmental change projections with the requisite accuracy and reliability needed to support national and international energy and environmental policies. Work towards this objective will also play a significant role in defining, testing, and integrating the SSI facilities and SSI crosscutting computer science and applied mathematics technologies into tools for scientific dsicovery.

- **Understand, model, and predict the behavior and properties of combustion processes and devices.** With teraflop scale computing resources and a concerted research program in combustion modeling, develop a new generation of combustion modeling tools for accelerated design of combustion devices meeting national goals of emission reduction and energy conservation. Through provision of a comprehensive understanding of the details of combustion, design engineers will have the computational tools to predict the chemical outcome of combustion processes with practical reliability, thus avoiding a time consuming, trial and error approach to the design of combustion devices (gas turbines, internal combustion engines, etc.) Work towards this objective will also play a significant role in defining, testing, and integrating the SSI facilities and SSI crosscutting computer science and applied mathematics technologies into tools for scientific discovery.

This initiative is a part of the broader President's ITRI. The Department's primary focus is advancing science through terascale computing. To accomplish these goals, DOE will partner with other agencies, particularly the National Science Foundation, to leverage the strengths of both agencies. In the case of research in global systems the research is already part of a broad interagency effort coordinated under the U.S. Global Change Research Program (USGCRP). Computer science and enabling technologies activities have been coordinated between agencies through the Computing, Information, and Communications R&D Subcommittee of the NSTC for a number of years. As a part of this initiative, closer ties will be established between DOE-funded activities and activities funded by other agencies. The development of enabling technologies for SSI will also be coordinated with the development of related technologies for ASCI through a joint CTR - ASCI research management committee. Where appropriate, joint interagency programs in other scientific disciplines may be established.

The CTR budget includes descriptions of the SSI computational science and enabling technology, as well as advanced computing and communications facilities elements of the SSI. In addition, the CTR budget includes funding for the competitive, peer reviewed selection of a small number of basic science applications to complement the two larger integrated applications efforts. The description of the Global Systems element of the SSI is included in the Biological and Environmental Research (BER) budget and the description of the Combustion Systems element is included in the Basic Energy Sciences (BES) budget. For reference, a high level summary of the proposed budget for the entire SSI initiative is given in the table below. These amounts will be reduced for the required SBIR/STTR assessments of 2.65%.

Objective	Program	FY 2000 Request
Earth's Global Environment	Biological and Environmental Research	$10 million
Combustion Systems	Basic Energy Sciences	$7 million
Basic Science Applications	Computational and Technology Research	$6 million
Computer Science and Enabling Technology	Computational and Technology Research	$16 million
SSI Facility Operations	Computational and Technology Research	$30 million
Staffing Resources	Science Program Direction	$1 million
Total SSI		$70 million

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Computational and Technology Research					
Mathematical, Information, and Computational Sciences	124,026	139,300	-466	138,834	184,575
Laboratory Technology Research	15,379	16,200	-58	16,142	14,300
Advanced Energy Projects	7,374	2,500	-5	2,495	0
Subtotal, Computational and Technology Research	146,779	158,000	-529	157,471	198,875
Use of Prior Year Balances	-1,714[a]	-1,573[a]	0	-1,573[a]	0
General Reduction	0	-529	+529	0	0
Total, Computational and Technology Research	145,065[b]	155,898	0	155,898	198,875

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $3,582,000 which has been transferred to the SBIR program and $215,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	%Change
Albuquerque Operations Office					
Los Alamos National Laboratory	14,614	13,034	10,894	-2,140	-16.4%
National Renewable Energy Laboratory	498	127	0	-127	-100.0%
Sandia National Laboratories	5,232	5,293	3,779	-1,514	-28.6%
Total, Albuquerque Operations Office	20,344	18,454	14,673	-3,781	-20.5%
Chicago Operations Office					
Ames Laboratory	2,290	1,939	1,490	-449	-23.2%
Argonne National Laboratory	16,869	15,430	13,176	-2,254	-14.6%
Fermi National Accelerator Laboratory	100	50	332	+282	+564.0%
Brookhaven National Laboratory	2,843	1,457	2,589	+1,132	+77.7%
Princeton Plasma Physics Laboratory	90	121	332	+211	+174.4%
Total, Chicago Operations Office	22,192	18,997	17,919	-1,078	-5.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	57,916	53,938	49,377	-4,561	-8.4%
Lawrence Livermore National Laboratory . . .	2,755	2,940	640	-2,300	-78.2%
Stanford Linear Accelerator Center	980	357	782	+425	+119.0%
Total, Oakland Operations Office	61,651	57,235	50,799	-6,436	-11.2%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education. . .	335	0	244	+244	+100.0%
Oak Ridge National Laboratory	19,434	10,415	6,876	-3,539	-34.0%
Thomas Jefferson National Accelerator Facility	190	100	283	+183	+183.0%
Total, Oak Ridge Operations Office	19,959	10,515	7,403	-3,112	-29.6%
Richland Operations Office					
Pacific Northwest National Laboratory	4,188	3,238	3,584	+346	+10.7%
All Other Sites[a]	18,445	49,032	104,497	+55,465	+113.1%
Subtotal, Computational and Technology Research	146,779	157,471	198,875	+41,404	+26.3%
Use of Prior Year Balances	-1,714[b]	-1,573 [b]	0	+1,573[b]	+100.0%
Total, Computational and Technology Research	145,065[c]	155,898	198,875	+42,977	+27.6%

[a] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

b Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

c Excludes $3,582,000 which has been transferred to the SBIR program and $215,000 which has been transferred to the STTR program.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. The MICS subprogram at Ames Laboratory conducts research in the materials scientific application pilot project, which focuses on applying advanced computing to problems in microstructural defects, alloys, and magnetic materials, and in computer science. The LTR subprogram at Ames also conducts research in the physical, chemical, materials, mathematical, engineering, and environmental sciences through cost-shared collaborations with industry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The MICS subprogram at ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The advanced computing research facility (ACRF) at ANL focuses on advanced computers in the IBM-SP family of technologies as well as the interaction of those architectures with advanced visualization hardware. The LTR subprogram at ANL also conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are chemistry of ceramic membranes, separations technology, near-frictionless carbon coatings, and advanced methods for magnesium production.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The LTR subprogram at BNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are materials for rechargeable lithium batteries, sensors for portable data collection, catalytic production of organic chemicals, and DNA damage responses in human cells.

Fermi National Accelerator Laboratory (Fermilab)

Fermilab is located on a 6,800-acre site about 35 miles west of Chicago, Illinois. The LTR subprogram at Fermilab conducts research in areas such as: superconducting magnet research, design and development, detector development and high-performance computing through cost-shared collaborations with industry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. The MICS subprogram at LBNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. LBNL participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The advanced computing research facility (ACRF) at LBNL currently focuses on very large scale computing on hardware in the T3E architecture from SGI-Cray including issues of distributing jobs over all the processors efficiently and the associated system management issues. LBNL manages the Energy Sciences Network (ESnet). ESnet is one of the world’s most effective and progressive science-related computer networks that provides worldwide access and communications to Office of Science (SC) facilities. In 1996, the National Energy Research Scientific Computing Center (NERSC) was moved from the Lawrence Livermore National Laboratory to LBNL. NERSC provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. The LTR subprogram at LBNL also conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are molecular lubricants for computers, advanced material deposition systems, screening novel anti-cancer compounds, and innovative membranes for oxygen separation.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. The MICS subprogram at LLNL involves significant participation in the advanced computing software tools program as well as basic research in applied mathematics.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. The Mathematical Information and Computational Sciences (MICS) subprogram at LANL conducts basic research in the mathematics and computer science and in advanced computing software tools. LANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The Advanced Computing Research Facility (ACRF) at LANL focuses on a progression of technologies from SGI - Cray involving Origin 2000 Symmetric Multiprocessor Computers linked with HiPPI crossbar switches. This series of research computers has been given the name “Nirvana Blue.”

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. ORISE provides support for education activities funded within the CTR program.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The MICS subprogram at ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ORNL also participates in several scientific application and collaboratory pilot projects. The LTR subprogram at ORNL also conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are high temperature superconducting wire, microfabricated instrumentation for chemical sensing, and radioactive stents to prevent reformation of arterial blockage.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The MICS subprogram at PNNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. PNNL also participates in several scientific application pilot projects. The LTR subprogram at PNNL also conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are mathematical simulation of glass production, interactions of biological polymers with model surfaces, and characterization of micro-organisms in environmental samples.

Princeton Plasma Physics Laboratory

The Princeton Plasma Physics Laboratory (PPPL), a laboratory located in Plainsboro, New Jersey, is dedicated to the development of magnetic fusion energy. The LTR subprogram at PPPL conducts research in areas that include the plasma processing of semiconductor devices and the study of beam-surface interactions through cost-shared collaborations with industry.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonapah, Nevada. The MICS subprogram at SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. SNL also participates in several scientific application and collaboratory pilot projects.

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located at the edge of Silicon Valley in California about halfway between San Francisco and San Jose on 426 acres of Stanford University land. The LTR subprogram at SLAC conducts research in areas such as advanced electronics, large-scale ultra-high vacuum systems, radiation physics and monitoring, polarized and high-brightness electron sources, magnet design and measurement, and controls systems through cost-shared collaborations with industry.

Thomas Jefferson National Accelerator Facility

The Thomas Jefferson National Accelerator Facility (TJNAF) is a basic research laboratory located on a 200 acre site in Newport News, Virginia. The LTR subprogram at the TJNAF conducts research in such areas as accelerator and detector engineering, superconducting radiofrequency technology, speed data acquisition, and liquid helium cryogenics through cost-shared collaborations with industry.

All Other Sites

The CTR program funds research at 71 colleges/universities located in 24 states. This line also includes funding of research awaiting distribution pending completion of peer review results.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram supports advanced computing research — applied mathematics, high performance computing, and networking — and operates supercomputer and associated facilities that are available to researchers 24 hours a day, 365 days a year. The combination of support for fundamental research, computational and networking tools development, and high-performance computing facilities provides scientists with the capabilities to analyze, model, simulate, and — most importantly — predict complex phenomena of importance to the Office of Science and to the Department of Energy.

Examples of the complex problems addressed by the Office of Science and the Department of Energy are: climate modeling, including the effects of greenhouse gases on global climate change; the combustion process, including the simulation of combustion in devices such as diesel engines; the subsurface transport of pollutants; the rational design of new materials to produce, for example, new alloys, superconductors, polymers, and catalysts; the effects of aging on the nuclear stockpile; and the analysis of vast amounts of real data from experiments at the Office of Science facilities for high energy physics, nuclear physics, materials sciences, chemical sciences, structural biology, and other disciplines.

For many such problems, traditional theoretical and experimental approaches may not be suitable; theory may be inadequate to handle the complexity, and experiments may not be feasible, because they are too dangerous, too expensive, or simply impossible owing to the length and time scales involved. Furthermore, experiments at the Office of Science facilities may generate millions of gigabytes (petabytes) of data per year (which would fill the disk drives of millions of today's personal computers) presenting significant computational and communications challenges in analyzing and extracting understanding from the data.

The increases in computational and communications capabilities achieved over the past two decades have made simulation a third branch of science that now complements theory and experiment and allows a new approach to previously intractable problems. However, as computational and communications capabilities have increased, so too have the challenges associated with effectively using these capabilities. The rate of increase in these capabilities itself poses formidable challenges. Significant hardware changes can occur as often as every 18 months; these, in turn, may require completely new approaches to computing software. This has already changed the way in which computation is performed in scientific disciplines such as materials science, biology, and fusion energy. Teams involving scientists from the disciplines as well as mathematicians; computer scientists; and experts in computer graphics, data management, and advanced computer networks are now required to address scientific problems that make use of the most modern computer and communications capabilities. This situation is quite different from that of even ten years ago when individual scientists could code and perform calculations with little or no support from others.

These same increases in computational and communications capabilities are having a second important impact on the way science is conducted. It is now possible for large geographically distributed teams to easily and effectively collaborate using major experimental facilities, computational resources, and data resources. The name given to such optimized linkages among geographically distributed resources is “collaboratories.” In the coming years, they are expected to play an increasingly important role in the Nation's scientific enterprise.

In order to enable scientists in the Office of Science to make effective use of these capabilities, the MICS subprogram supports research in three areas:

- Applied Mathematics. Research on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems such as fluids, magnetized plasmas, or protein molecules. This includes, for example, methods for solving large systems of partial differential equations on parallel computers, techniques for choosing optimal values for parameters in large systems with hundreds to hundreds of thousands of parameters, improving our understanding of fluid turbulence, and developing techniques for reliably estimating the errors in simulations of complex physical phenomena.
- Computer Science. Research in computer science to enable large scientific applications through advances in massively parallel computing such as very lightweight operating systems for parallel computers, distributed computing such as development of the Parallel Virtual Machine (PVM) software package which has become an industry standard, and large scale data management and visualization. The development of new computer and computational science techniques will allow scientists to use the most advanced computers without being overwhelmed by the complexity of rewriting their codes every 18 months.
- Networking. Research in high performance networks and information surety required to support high performance applications — protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and networks. The development of high speed communications and collaboration technologies will allow scientists to view, compare, and integrate data from multiple sources remotely.

In all of these areas — applied mathematics, computer science, and networking — the requirements far exceed the current state-of-the-art; furthermore, the requirements far exceed the tools that the commercial marketplace will deliver. In addition to these fundamental research efforts, the MICS subprogram takes the results of these efforts and forms partnerships with users in scientific disciplines to validate the usefulness of the ideas and to develop them into tools. MICS also provides the advanced computing and communications facilities that enable scientists to use these tools.

MICS provides two types of advanced computing and communications facilities. The first type of facility enables scientists to use the tools developed. Examples are NERSC and ESnet. The second type of facility is itself a research project. The principal current examples of this type of facility are the Advanced Computing Research Facilities (ACRFs) at Argonne National Laboratory, Lawrence Berkeley National Laboratory, and Los Alamos National Laboratory that represent the evolution of the High Performance Computing Research Centers and were established as part of the High Performance Computing and Communications initiative. The ACRFs combine research in computer software and hardware with targeted applications. One of the major issues that these facilities attempt to address is how different choices in computer architecture affect the ability of a system to scale to very large numbers of processors and very high performance. In order to address these issues, computers at a scale that push the state-of-the-art must be sited at the ACRFs. These computers enable research in computers and computing, but they are not sufficiently mature or robust for production computing by large numbers of users.

Partnerships with the scientific disciplines are an important management philosophy in the MICS subprogram. Partnerships with the scientific disciplines are critical, because they test the usefulness of current advanced computing research, enable MICS to transfer the results of this research to scientists in the disciplines, and help define promising areas for future research. Finally, to develop future generations of scientists with the breadth of skills required to be effective both in advanced computing research and in interacting with disciplinary sciences, MICS supports the Computational Science Graduate Fellowship program.

The MICS subprogram includes the Department's participation in the President's Next Generation Internet (NGI) Initiative. This initiative will create the foundation for more powerful and versatile networks of the 21st century, just as previous federal investments in information technology R&D created the foundation for today's Internet. DOE's participation in this initiative is focused on network requirements that will enable data-intensive scientific research not now possible because of network limitations. It is anticipated that the results and "spinoffs" of this research, after testing and prototyping by the scientific community, will impact broad commercial use of networks.

DOE's NGI research program is focused on discovering, understanding, developing, testing and validating the networking technologies needed to enable wide area, data intensive and collaborative computing that is not currently possible. This program will integrate scientists working on fundamental research in applied mathematics, computer science, and networking with scientists working on DOE applications to develop new ways to link scientists with DOE's major scientific user facilities and computational centers. Such research is needed to enable effective use of petabyte/year High Energy and Nuclear Physics facilities such as the Relativistic Heavy Ion Collider (RHIC); to provide remote visualization of terabyte to petabyte data sets from computational simulation; to develop advanced collaboratories; and to enable effective remote access to tomorrow's advanced scientific computers. These applications share two important characteristics. They all involve extremely large data sets, and they all require that scientists be able to interact with the data in (nearly) real time. Current network technology limitations significantly limit our ability to address either of these characteristics.

The NGI activities are critical for DOE's fundamental science research. For example, using the current Internet, it would take about 2,500 hours to transmit one day's data from RHIC to one remote site for analysis. Typical RHIC experimental collaborations involve thousands of scientists and hundreds of institutions spread across the country and the world. Management of scientific data is further complicated because the data must be managed in large units. This is very different than data management in the commercial sector. For example, a standard telecommunications billing record is only 180 bytes long; a large web page is 500 kilobytes; but the data from a global climate model at any given time during the simulation (a single time step) may be greater than a gigabyte or 2,000 times as large as that of a large web page!

The technologies developed for commercial network traffic are simply inadequate for scientific network traffic. Significant *research* is needed to enable today's commercial networks to be used for scientific data. This research must include advanced protocols, special operating system services for very high speed, and very advanced network control. For example, a coast to coast gigabit/second network may have as much as a gigabit of data in transit at any one time. If this is scientific data this might be one packet. Current protocols would require that all of the switches along the way be able to buffer a gigabit of data at very high rate, which is not possible with today's switches. Therefore research is required. The issues related to managing a single gigabit packet versus 2,000 500 kilobit packets are very different.

In addition to the complications posed by the transmission of large data sets, there are additional complications that result from the many different kinds of network devices, network-attached devices, and services that need to be integrated together. Examples of the components and services that need to be integrated include: network resources, data archives on tape, high performance disk caches, visualization and data analysis servers, authentication and security services, and the computer on a scientist's desk. This type of integration, as well as the issues of improving the performance of the individual components, all require significant research because the issues are currently not well understood. Indeed, the first identification of many of these issues is the result of previous work in collaboratories and visualization supported by this subprogram. Thus DOE's participation in the NGI builds on previous results of the MICS subprogram to address critical issues in the network. Furthermore, the differences between the requirements of commercial networks and networks for scientific research require DOE to conduct this research because these tools and technologies will not be developed by commercial R&D. However, there will be tremendous "spinoff" benefits to the Internet in general after the research is completed and the results enhance commercial networks.

Scientific Simulation Initiative

This budget also includes the MICS subprogram's contribution to DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs. The SSI couples research in advanced scientific applications in the programs of the Office of Science with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between CTR and the other program offices in SC.

It is a requirement for the success of this program to use the expertise that exists in national laboratories, universities, and industry and, where appropriate, formation of multidisciplinary teams of researchers. Participants from various institutions will be encouraged through open peer reviewed competitions. Also, strong partnerships with the DOE ASCI program and complementary programs in other agencies will be essential. The overview of the integrated program is given in the Program Mission statement of the CTR budget; however, the specific contributions of the MICS subprogram are described below.

MICS contributes to the SSI in three ways:

Management of the Computer Science and Enabling Technology (CSET) component of the SSI;

Management of the SSI Advanced Computing and Communications Facilities; and

Management of the peer reviewed selection process for the basic science application efforts to be initiated in FY 2000.

The goal of the CSET component of the SSI is to develop needed software systems, to deploy these systems into the DOE computing infrastructure, to support users, and to conduct the needed research to address future problems, all with close involvement of the applications scientists and the computer systems providers. CSET teams will also work closely with the vendor community to ensure that needed capabilities are incorporated into products, systems, and services. Working with the university research community, CSET teams will ensure a steady flow of young researchers into the field and will form long-term collaborations in the areas needed by scientific simulation. CSET teams will also establish natural partnerships with the DOE ASCI program and with the NSF Partnerships for Advanced Computational Infrastructure (PACI) program, which are addressing complementary goals. These partnerships could result in the joint funding of research and development activities and joint deployment of infrastructure capabilities. CSET is a critical crosscutting activity for the Scientific Simulation Initiative — one that will enable the program to accomplish far more than if applications teams were required to develop all the necessary software and infrastructure themselves. Through the sharing of common tools and technologies, the CSET activities will dramatically improve the cost-effectiveness of the SSI. In order to accomplish these goals, CSET must support a vigorous research program as well as significant development and software deployment activities to address the following critical issues.

First, despite considerable progress during the past ten years in making massively parallel computer systems usable for applications, much remains to be done. Computer systems targeted for SSI will scale from approximately 1,000 nodes today to 5,000 or 10,000 nodes for systems in 2004. This scaling will require substantial improvements in parallel computing tools, parallel I/O (input/output) systems, data management, algorithms, and program libraries. Not only will the number of compute nodes increase, but the nodes themselves will become more complex, as systems designers are forced to introduce more layers of memory hierarchy to maintain performance and develop new hardware features to support rapid communication and synchronization. The end result five years from now will be hardware systems that, while showing their roots in today's systems, will be substantially different and substantially more complex and therefore more challenging to exploit for high performance.

Second, because applications software systems typically outlive hardware by an order of magnitude (i.e., computer hardware typically has a useful lifetime of three years, whereas large-scale scientific codes last one to two decades), new software must be designed for machines not only for the near future but for the next decade. This effort will require close working relationships between code developers from the applications areas and computer scientists who are involved in next-generation systems and architecture design.

Third, the applications themselves are getting more complex. They are incorporating more sophisticated physical models, are using advanced numerical techniques (e.g., adaptive mesh refinement, unstructured and implicit solvers, and hierarchical methods), and are beginning to be combined into large-scale “simulation systems” that include the linkage of two or more previously stand alone models (e.g., ocean-atmosphere-biosphere or fluid-structures-chemistry). Furthermore, in some cases these models are being driven by an optimization environment to enable them to address policy questions.

Finally, in addition to rapidly changing hardware and applications targets, the user and development community is also evolving. No longer can groups afford to work only with local collaborators or to use only locally available hardware and software resources. The development and user environments of the near future will need to enable ubiquitous collaboration and distributed computing capabilities to address these complexities. As the applications codes themselves become more interdisciplinary, so too will the teams that write them. As the need to incorporate deep knowledge of computer science techniques into future codes increases, so will the need to form long-term collaborations among applications scientists and computer scientists and mathematicians. These unavoidable trends mean that the problem-solving environments of the future will need to support human-to-human interactions as easily as we support computer to computer interactions today.

The management of SSI Computing and Communications facilities also poses challenges. Specifying, developing procurement specifications for, and finally delivering installed SSI facilities require great skill and experience. All of the facilities must work together because the performance of the system is determined by the slowest component. The SSI facilities must provide the linkage between the computing environment developed for the user and the systems management and systems integration required to support these environments. The SSI requires three distinct types of computing facilities: computing, networking and associated supporting hardware.

DOE will establish an open solicitation process that seeks the widest participation in establishing its terascale computing infrastructure, including competition among national laboratories, universities, and industry, based on their qualifications. The sites for the major teraflop computers will be selected through peer-reviewed competition. A number of considerations are important in selecting organizations to manage and locations at which to site SSI facilities. One of the most important is an expertise to perform the necessary computing systems integration into the existing nationwide DOE Office of Science computing infrastructure. These large-scale systems have requirements for scalable systems management that will enable relatively small systems administration teams to manage systems with 1000's of nodes and 10,000's of processors. These systems also need to be tightly integrated with data storage environments, mass stores, visualization environments, and distributed computing frameworks. Other considerations include incremental site preparation costs, the cost of connecting at very high speed to the networking infrastructure, and site financial leverage in providing operational support to the facility.

Finally, MICS will manage the open peer reviewed competition among basic science disciplines to select a small number for initial inclusion in the initiative. These applications will be chosen from throughout the portfolio of the Office of Science based on the scientific and technical merit of the proposals; the importance to DOE missions; and the readiness of the area and the associated scientific communities to move quickly to terascale computers.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	47,857	51,560	71,407	+19,847	+38.5%
Advanced Computation, Communications Research and Associated Activities	76,169	83,800	108,682	+24,882	+29.7%
SBIR/STTR	0	3,474	4,486	+1,012	+29.1%
Total, Mathematical, Information, and Computational Sciences	124,026	138,834	184,575	+45,741	+32.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

Mathematical, Computational, and Computer Sciences Research

- **Applied Mathematics:** Research on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems. This activity supports research at DOE laboratories, universities, and private companies to provide the DOE laboratory community and the wider national scientific and engineering communities with the most powerful and effective mathematical and computational tools for modeling, analyzing, and simulating complex phenomena in the core disciplinary and technology areas of DOE. Laboratory, academic, and industry researchers supported by the program work at laboratory sites with DOE mentors. To accomplish its goals, the program supports research in a number of areas including: **Mathematical Physics** including string theory, superstring theory, geometry of space-time, and quantum effects; **Ordinary and Partial Differential Equations** including numerical methods, high performance algorithms, massively parallel algorithms, distributed computing, novel gridding schemes, numerical linear algebra, iterative methods, sparse solvers, and dense solvers; **Control Theory** including differential-algebraic systems, order reduction, queuing theory; **Shock Wave Theory** including hyperbolic systems, multipole expansions, mixed elliptic-hyperbolic problems, and wavelet transforms; **Fluid Dynamics** including compressible, incompressible, and reacting flows, turbulence modeling, and multiphase flows; **Dynamical Systems** including chaos-theory and control, and bifurcation theory; **Programming and Optimization** including linear and nonlinear programming, interior-point methods, and discrete and integer programming; and **Geometric and Symbolic Computing** including minimal surfaces and automated theorem proving. The FY 2000 budget includes the continuation of work initiated in FY 1999

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
to develop the mathematical basis for modeling and simulating complex stochastic phenomena of the type that arise in vital DOE areas such as global climate modeling, environmental remediation, and stockpile stewardship. CTR will provide opportunities for college faculty and students to spend time at DOE laboratories, to participate in world-class research projects. Faculty/Student Science Teams will visit DOE labs during the academic/summer semesters, be involved in conducting research, writing proposals, utilizing technology and pursuing technical or scientific careers. Primary goals of the Science Teams are to build long-term partnerships among DOE laboratories and provide faculty/students with a deeper understanding of DOE science associated needs for research and development. Funds will be provided to pay for faculty/student stipends, travel, housing, and subsidizing laboratory scientists' time for this activity ($1,947,000).	23,576	25,232	27,179
■ **Computer Science:** Research in computer science to enable large scientific applications. This activity supports research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization. The first area includes research in protocols for message passing and parallel input/output (IO) as well as tools to monitor the performance of scientific applications. The second area includes research in effective techniques for retrieving data with complex internal structure from massive data archives that may be geographically distributed as well as advanced techniques for visualizing very large scale scientific data.	14,000	14,000	14,000

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Advanced Computing Software Tools:** R&D to develop the results of fundamental research in applied mathematics and computer science into an integrated set of tools that can be used by scientists in various disciplines to develop high performance scientific applications (e.g., to simulate the behavior of materials) that will have a useful life spanning many generations of computer hardware. These tools will include capabilities for representing complex geometries, solving diverse numerical equations, simplifying multi-language parallel execution, evaluating and enhancing code performance, and dynamically steering calculations during execution. This effort began as a part of the DOE2000 initiative.	5,000	5,000	5,000
■ **Scientific Applications Pilot Projects:** R&D to apply computational techniques and tools developed in the Advanced Computing Software Tools effort to basic research problems in order to test the usefulness of current advanced computing research, transfer the results of this research to the scientific disciplines, and help define promising areas for future research. Examples of pilot projects include: research in simulations of the earth's climate; research in the fundamental structure and properties of magnetic materials; creation of advanced tools to understand the chemistry of actinides; and partnerships with experimental disciplines such as high energy and nuclear physics, human genomics, and crystallography to improve the ability of these disciplines to manage and analyze the petabytes of data (that would fill the hard disks of millions of today's PC's) produced by their experiments and simulations. These efforts represent the evolution of the Grand Challenge projects that were initiated as part of DOE's component of the Federal High Performance Computing and Communications program, which started in FY 1991. These projects will now be phased out in an orderly manner	5,281	7,328	3,785

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Scientific Simulation Initiative (SSI) Algorithms, Models, Methods and Libraries:** New classes of algorithms will need to be developed to effectively utilize SSI systems. SSI computers will be characterized by large-scale distributed shared memory, with deep memory hierarchies. To achieve maximum performance, new hierarchical algorithms and methods need to be developed that can take advantage of these architecture features. In addition, mathematical techniques that are already under development may yield fundamentally new ways to conduct individual simulations and ensemble calculations, improving predictability and our understanding of errors in computations. New strategies for building mathematical software based on components are also likely to make a large contribution to programmer effectiveness for the SSI applications.	0	0	2,947
■ **SSI Problem Solving Environments and Tools (PSET):** A major challenge for CSET will be the development of an integrated problem solving environment that supports the rapid construction and testing of applications codes. These environments need to support the most advanced parallel tools and libraries and enable users to collaborate on the development of codes, planning runs, debugging and performance analysis. PSET systems will also allow the user to monitor jobs visually and to steer computations from their desktop and to share these results with others.	0	0	2,920
■ **SSI Distributed Computing and Collaboration Technology (DCCT):** Many SSI applications teams will be distributed around the country. They need the capability to work together not only to develop codes, but also to share data, design experiments, plan work and jointly conduct long running jobs. DCCT will support the creation of a software technology base to support SSI simulations that will enable users to run jobs at remote sites and migrate data from one site to another. Distributed computing technology will enable users to begin to see a single logical view of the DOE computing infrastructure and request, coordinate, and manage resources from multiple sites to attack a problem.	0	0	2,920

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **SSI Visualization and Data Management Systems:** Simulations run on 10 teraflop or 40 teraflop class computers will generate 10's or 100's of Terabytes of output per job. Advanced scientific visualization and analysis systems will be needed to translate this mass of output to human understanding. Some data will best be analyzed visually while other data will need to be post-processed to extract features and statistics. Both forms of analysis will need sophisticated data management systems to enable the rapid and facile manipulation of datasets. Large-scale databases will be used to manage data from simulations and advanced data organization techniques will support rapid and hierarchical traversals of data providing the user the possibility of flying through data in real-time. Associated capital requirements for large scale data management and visualization testbeds are also supported . . .	0	0	6,815
■ **SSI Basic Science Applications:** Support two basic science SSI application efforts. These efforts will be selected through a competitive process that evaluates the scientific and technical merit of the proposed project, the potential of the proposed work to make significant new science possible, and the readiness of the scientific discipline and associated scientific community to make early use of terascale computers.	0	0	5,841
Total Mathematical, Computational, and Computer Sciences Research	47,857	51,560	71,407
Advanced Computation, Communications Research, and Associated Activities			
■ **Networking:** Research in high performance computer networks and information surety required to support high performance computer applications — protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and both local area and wide area networks. In addition, this activity supports research in network protocols to enable applications to request, and be guaranteed, certain levels of network capability.	5,987	4,500	4,500

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Collaboratory Tools:** R&D to develop the results of fundamental research in computer science and networking into an integrated set of tools to enable scientists to remotely access and control facilities and share data in real time. In order to accomplish this goal a number of issues are under investigation including: definition and demonstration of a general and modular security architecture that can protect open network applications such as control of experimental devices; development of a modular electronic notebook prototype that can be used in a number of desktop computer environments to enable the sharing of scientific results, data from scientific instruments, and design of scientific procedures; development of tools to manage distributed collaborations such as tools for managing multipoint videoconferences ranging from the current "whoever is speaking has the floor" to more formal meetings where a meeting leader controls who has the "floor"; development of advanced techniques for managing and returning to the electronic record of the collaboration; and exploration of techniques such as virtual reality to enable large groups to work together effectively at a distance. This effort began as a part of the DOE2000 initiative.	3,000	3,000	3,000
■ **National Collaboratory Pilot Projects:** R&D to test, validate, and apply collaboratory tools in partnership with other DOE programs. The two pilot projects are: (1) the Materials MicroCharacterization Collaboratory, a partnership with Basic Energy Sciences and Energy Efficiency and Renewable Energy to provide remote access to facilities located at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Argonne National Laboratory, and the National Institute of Standards and Technology, and the University of Illinois for electron beam microcharacterization of materials; and (2) the Diesel Combustion Collaboratory, a partnership with Basic Energy Sciences, Energy Efficiency and Renewable Energy, and three U.S. manufacturers of diesel engines, to link the research and researchers at Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and the University of Wisconsin with efforts and researchers at industrial			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
laboratories in Indiana and Michigan to develop the next generation of clean diesel engines. This effort began as a part of the DOE2000 initiative. These partnerships with the scientific disciplines and the technology programs enable MICS to be particularly successful in bringing advances in advanced computing research to bear on important problems faced by scientists in other disciplines. In addition, they provide important feedback to the researchers on what problems are most important.	3,000	3,000	3,000
■ **National Energy Research Scientific Computing Center (NERSC):** NERSC, located at LBNL, provides high performance computing for investigators supported by the Office of Science. The Center serves 3,500 users working on about 700 projects; 35 percent of users are university based, 60 percent are in National Laboratories, and 5 percent are in industry. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. This file storage system, the Archival Systems Upgrade, is a major item of equipment in FY 2000 with a total estimated cost of $2,000,000.	26,500	26,500	27,500
■ **Advanced Computing Research Facilities (ACRFs):** ACRFs support advanced computational hardware testbeds for scientific application pilot projects and fundamental research in applied mathematics and computer science. Because many of the issues to be investigated only appear in the computer systems at significantly larger scale than the computer manufacturers' commercial design point, these facilities must procure and develop software to manage and make useful the largest scale systems that can be afforded. In addition, the ACRFs, taken together, must have a full range of different computer architectures to enable comparison and reduce overall program risk. These all involve significant research efforts, often in partnership with the vendors to resolve issues including operating system stability and performance, system manageability and scheduling, fault tolerance and recovery, and details of the interprocessor communications network.			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Therefore, all of these systems are managed as research programs and not as information technology investments. ACRFs are located at Los Alamos National Laboratory (Nirvana Blue partnership with the DOE Biological and Environmental Research (BER) program and Defense Programs (DP), based on SGI/Cray Technology); Argonne National Laboratory (IBM-SP); and Lawrence Berkeley National Laboratory (SGI/Cray T3E and Next Generation procurement). Related capital equipment needs such as high speed disk storage systems, archival data storage systems and high performance visualization hardware are also supported. The ACRFs represent the evolution of the High Performance Computing Research Centers that DOE initiated as a part of the Federal High Performance Computing and Communications initiative.	22,895	17,411	11,876

- **Energy Sciences Network (ESnet):** ESnet provides worldwide access to the Office of Science facilities, including: advanced light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; ACRFs; and other leading-edge science instruments and facilities. ESnet provides the communications fabric that links DOE researchers to one another and forms the basis for fundamental research in networking, enabling R&D in collaboratory tools, and applications testbeds such as the national collaboratory pilot projects. To provide these facilities, ESnet management at LBNL contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM) and Wave Division Multiplexing (WDM). ESnet management provides system integration to provide a uniform interface to these services for DOE laboratories. In addition, ESnet management is responsible for the interfaces between the network fabric it provides and the worldwide Internet including the National Science Foundations's very high performance backbone network service that provides high performance connections to many research universities. One reason that ESnet, in the words of the 1998 external review committee, is able to provide the capabilities and services to its users "at significantly lower budgets than other

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
agencies" is its management structure with strong user and site coordination committees. This management structure is built on DOE's experience in operating large user facilities. Related capital equipment needs are also supported such as high speed network routers, ATM switches, and network management and testing equipment.	14,787	14,787	14,787

- **Next Generation Internet (NGI):** DOE's program will focus on developing, testing and validating the networking technologies needed to enable wide area, data intensive and collaborative computing. The program, which began in FY 1999, has three subcomponents. First, research in basic underlying technologies such as: protocols and techniques for coordinating multiple, heterogeneous network-attached devices; congestion and flow control techniques; multi-gigabit end system interfaces, analyzers, and switches along with mechanisms to reduce operating system overhead for data transfers; mechanisms to provide application controlled Class of Service and Quality of Service; and middleware to provide Internet Protocol (IP), ATM, and WDM resource and admission control, scheduling, management, prioritization, accounting, and debugging. Second, Application-Network Technology-Network Testbed Partnerships to: integrate and test advanced network R&D and testbeds with DOE mission applications such as HENP Data, remote visualization of simulation results, advanced collaboratories; define what network & middleware services are required to permit these applications to effectively run over wide area networks; define the features and the API's necessary to allow the application and middleware to communicate; integrate local and wide-area network technologies to create distributed collaboratories; and integrate Differentiated Services, or other Quality of Service functions, into wide area networks and production network testbeds without compromising the existing production network services. Third, DOE-University Technology Testbeds focused on: R&D to implement advanced network services across multiple, interconnected networks; deployment of advanced differentiated services technology

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
across autonomous networks when priority flow represents a significant fraction of the available capability; development and testing of advanced tools to manage "peering" of networks with advanced services; cross-domain implementations of security and authentication technologies; development and testing of network performance monitoring and characterization software which applications can use in this environment to optimize their performance; and development of policy frameworks and specification languages to facilitate the negotiation of capabilities across autonomous system boundaries.	0	14,602	14,602

- **SSI Research Computing Facilities and Network Infrastructure:** Initiation of a procurement for one 5 Teraflop-class computer system and associated data archive facilities in the third quarter of FY 2000. This activity includes not only procurement of the computing and storage systems but also the associated operational costs and facility improvements which will be required. This process will have two distinct stages. DOE will establish an open solicitation process that seeks the widest participation in establishing its terascale computing infrastructure, including competition among national laboratories, universities, and industry, based on their qualifications. The sites for the major teraflop computers will be selected through peer-reviewed competition. A number of considerations are important in selecting organizations to manage and locations at which to site SSI facilities. One of the most important is an expertise to perform the necessary computing systems integration into the existing nationwide DOE Office of Science computing infrastructure. These large-scale systems have requirements for scalable systems management that will enable relatively small systems administration teams to manage systems with 1000's of nodes and 10,000's of processors. These systems also need to be tightly integrated with data storage environments, mass stores, visualization environments, and distributed computing frameworks. Other considerations include incremental site preparation costs, the cost of connecting at very high speed to the networking infrastructure, and site

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
financial leverage in providing operational support to the facility. After the site is selected, the site must conduct an open competition to procure the 5 teraflop-class computer system as well as the other supporting computing and data storage systems. This activity also includes significant enhancements to the ESnet infrastructure to support access to the SSI computer facility by SSI scientists. SSI computing facilities and remote sites require very high performance network facilities to be effective. Planning estimates indicate that aggregate network data flow into and out of SSI facilities must be near 100 gigabits/second, almost 200 times faster than the fastest links on today's ESnet. In addition, remote sites with major participation in SSI science areas and CSET require significantly greater network capabilities than ESnet can provide within its current funding profile. Enhanced network services will be provided to remote sites on the basis of need and the resources available. The balance of funding between the computer facility and enhanced networking will be determined by detailed review after the selection of the computer facility site. However, preliminary estimates indicate that the computer facility will require between 80 percent and 85 percent of the funding in this activity. Associated requirements for capital equipment and GPP funding are included here..	0	0	29,417
Total, Advanced Computation, Communications Research, and Associated Activities	76,169	83,800	108,682
SBIR/STTR			
■ In FY 1998, $3,004,000 and $180,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	3,474	4,486
Total, Mathematical, Information, and Computational Sciences	124,026	138,834	184,575

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Mathematical, Computational, and Computer Sciences Research	
■ Increase in funding will provide opportunities for college faculty and students to spend time at DOE laboratories to participate in world class research projects.	+1,947
■ Close out all scientific application pilot projects in an orderly fashion in mid-FY 2000.	-3,543
■ Initiate support for SSI's Computational Sciences and Enabling Technology and Basic Science Applications..	+21,443
Total, Mathematical, Computational, and Computer Sciences Research	+19,847
Advanced Computation, Communications Research, and Associated Activities	
■ Cost-of-living increase for operations of NERSC.	+1,000
■ Reduced support for ACRF's including termination of the ACRF at ANL in mid-FY 2000.	-5,535
■ Support for SSI's Research Computing Facilities and Network Infrastructure.	+29,417
Total, Advanced Computation, Communications Research, and Associated Activities	+24,882
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+1,012
Total Funding Change, Mathematical, Information, and Computational Sciences	+45,741

Laboratory Technology Research

Mission Supporting Goals and Objectives

The mission of the Laboratory Technology Research (LTR) subprogram is to support high risk, energy related research that advances science and technology to enable applications that could significantly impact the Nation's energy economy. LTR fosters the production of research results motivated by a practical energy payoff through cost-shared collaborations between the Office of Science (SC) laboratories and industry.

An important component of the Department's strategic goals is to ensure that the United States maintains its leadership in science and technology. LTR is the lead program in the Office of Science for leveraging science and technology to advance understanding and to promote our country's economic competitiveness through cost-shared partnerships with the private sector.

The National Laboratories under the stewardship of the Office of Science conduct research in a variety of scientific and technical fields and operate unique scientific facilities. Viewed as a system, these ten laboratories — Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility — offer a comprehensive resource for research collaborations. The major component of the LTR research portfolio consists of investments at these laboratories to conduct research that benefits all major stakeholders — the DOE, the industrial collaborators, and the Nation. These investments are further leveraged by the participation of an industry partner, using Cooperative Research and Development Agreements (CRADAs). Another LTR program component provides rapid access by small business to the research capabilities at the SC laboratories through agile partnership mechanisms including personnel exchanges and technical consultations with small business. The LTR subprogram currently emphasizes three critical areas of DOE mission-related research: advanced materials processing and utilization, intelligent processes and controls, and energy-related applications of biotechnology.

Performance Measures

- Initiate about 7 Laboratory Technology Research projects that address the Department’s top priorities for science and technology, through cost-shared research partnerships with industry.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Laboratory Technology Research	14,983	12,751	13,921	+1,170	+9.2%
SBIR/STTR	0	423	379	-44	-10.4%
Congressional Direction	396	2,968	0	-2,968	-100.0%
Total, Laboratory Technology Research	15,379	16,142	14,300	-1,842	-11.4%

Detailed Program Justification

(dollars in thousands)		
FY 1998	FY 1999	FY 2000

Laboratory Technology Research

- This activity supports research to advance the fundamental science and technology at the Office of Science laboratories toward innovative energy applications. Through CRADAs, the SC laboratories enter into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. In FY 2000, about 7 new Laboratory Technology Research projects will be initiated. The research portfolio consists of approximately 100 projects and emphasizes the following topics: advanced materials processing and utilization, intelligent processes and controls, and energy-related applications of biotechnology. Efforts underway include the exploration of (1) a process to produce ultra-smooth diamond coatings on rotating and sliding mechanical parts in order to reduce energy consumption, improve product reliability, and reduce toxic emissions to the environment; (2) a new family of wireless, single-chip luminescent-sensing devices for use in monitoring of environmental pollutants and in high throughput screening of new therapeutic drugs; and (3) an x-ray imaging module, consisting of a cadmium zinc telluride detector and an application-specific integrated circuit, to determine bone density in the diagnosis of osteoporosis by performing whole

	FY 1998	FY 1999	FY 2000
body scans with lower dose rate and higher resolution. A small but important component of this activity provides industry, particularly small businesses, with rapid access to the unique research capabilities and resources at the SC laboratories. These research efforts are usually supported for a few months to quantify the energy benefit of a specific problem posed by an industry. Recent projects supported the development of (1) a low-temperature oxygen plasma technology for remediation of soils contaminated by pesticides and other chemicals; (2) a new class of fluids that can transfer heat more efficiently than conventional fluids and offer several energy-related benefits, including decreased pumping power needs and reduction in required heat exchanger size, for use in the transportation, electronics, and textile industries; and (3) improved catalytic materials, which can lead to substantial energy savings in petroleum refining and chemical manufacturing.	14,983	12,751	13,921
SBIR/STTR			
■ In FY 1998, $391,000 and $24,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	423	379
Congressional Direction			
■ Funds the University of Southwestern Louisiana (per FY 1997 Congressional Direction).	396	2,968	0
Total, Laboratory Technology Research	15,379	16,142	14,300

(dollars in thousands)

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Laboratory Technology Research	
■ Increase in multiyear technology research partnership projects.	+1,170
SBIR/STTR	
■ Decrease in SBIR/STTR due to decrease in operating expenses.	-44
Congressional Direction	
■ Reduction is due to completion of Congressionally directed projects	-2,968
Total Funding Change, Laboratory Technology Research.	-1,842

Advanced Energy Projects

Mission Supporting Goals and Objectives:

The Advanced Energy Projects (AEP) subprogram funded research that established the feasibility of novel, energy-related concepts that span the Department's energy mission and goals. Funded projects were based on innovative ideas that spanned multiple scientific and technical disciplines and did not fit into any other DOE program area. A common theme for each project was the initial linkage of new research results to an energy application with a potentially significant payoff. Typically, AEP supported projects up to a level of about $250,000 per year for a period of about 3 years. Projects were selected from proposals submitted by universities and national laboratories. Funding criteria emphasized scientific merit as judged by external peer review.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Advanced Energy Projects	7,374	2,429	0	-2,429	-100.0%
SBIR/STTR	0	66	0	-66	-100.0%
Total, Advanced Energy Projects	7,374	2,495	0	-2,495	-100.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Advanced Energy Projects			
■ Support for high-risk, high-payoff research at universities and national laboratories established the feasibility of novel energy related concepts that were at an early stage of scientific definition. Final funds for these projects were provided in FY 1999.	7,374	2,429	0

	FY 1998	FY 1999	FY 2000
(dollars in thousands)			
SBIR/STTR			
■ In FY 1998, $187,000 and $11,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 amount is the estimated requirement for the continuation of the SBIR and STTR programs.	0	66	0
Total, Advanced Energy Projects	7,374	2,495	0

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Advanced Energy Projects	
■ Termination of existing AEP program. The decision to terminate the AEP subprogram resulted from a change in CTR program priorities	-2,429
SBIR/STTR	
■ Decrease in SBIR/STTR due to termination of the program.	-66
Total Funding Change, Advanced Energy Projects	-2,495

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	397	70	4,000	+3,930	+5,614.3%
Capital Equipment (total)	6,912	6,275	11,275	+5,000	+79.7%
Total, Capital Operating Expense	7,309	6,345	15,275	+8,930	+140.7%

Major Items of Equipment (*TEC $2 million or greater*)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 1998	FY 1999	FY 2000	Accept- ance Date
Archival Systems Upgrade - LBNL	2,000	0	0	0	2,000	FY 2002
Total, Major Items of Equipment		0	0	0	2,000	

Multiprogram Energy Laboratories - Facilities Support

Program Mission

The Multiprogram Energy Laboratories - Facilities Support (MEL-FS) program provides line item construction funding (i.e., projects with a total estimated cost of $5,000,000 or above) for general purpose facilities to support the infrastructure of the five Office of Science multiprogram national laboratories. These are: Argonne National Laboratory - East (ANL-E), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). These laboratories are government-owned, contractor-operated (GOCO) and have over 1,100 buildings with 14.3 million gross square feet of space and an estimated replacement value of over $9,000,000,000. Total operating funding for these laboratories is over $3,000,000,000 a year. The Office of Science manages this program to provide a comprehensive, prioritized and equitable approach to its stewardship responsibility for the general purpose support infrastructure of these laboratories.

The program also provides funding for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Program Goal

To ensure that the support facilities at the multiprogram laboratories can meet the Department's research needs in a safe, environmentally sound, and cost-effective manner primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure.

Program Objectives

- To correct Environment, Safety and Health (ES&H) inadequacies.
- To reduce risk of operational interruptions due to failed support systems.
- To provide cost effective operations and reduce maintenance costs.
- To provide quality space for multiprogram research and support activities.
- To preserve the government investment in the physical plant of the laboratories.
- To promote performance-based infrastructure management.

Performance Measures

Performance measures related to the MEL-FS program are continuously being refined to ensure that they: 1) incorporate external/internal customer inputs; 2) drive performance; 3) address the strategic plan; and 4) focus on the effectiveness of the laboratory system. Current performance measures include:

- Support of line item construction funding to reduce risk, ensure continuity of operations, avoid or reduce costs and increase productivity.

  Expectation: Fund highest priority needs based on scoring from Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix.

- Overall condition of laboratory buildings.

  Expectation: Increase the percentage of facilities rated adequate.

- Excellence in project management.

  Expectation: Increase the percentage of projects completed within baseline cost and schedule.

Significant Accomplishments and Program Shifts

- Progress in Line Item Projects - Two projects are scheduled for physical completion in FY 2000: the Building Electrical Services Upgrade- Phase I at ANL-E and the Electrical Services Rehabilitation-Phase IV at LBNL.

- Continue the Payments in Lieu of Taxes (PILT) for ANL-E and BNL.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Multiprogram Energy Laboratories-Facilities Support					
Multiprogram Energy Laboratories-Facilities Support	21,247	21,260	0	21,260	21,260
Use of Prior Year Balances	-336[a]	-13[a]	0	-13[a]	0
Total, Multiprogram Energy Laboratories-Facilities Support	20,911	21,247	0	21,247	21,260

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	10,892	7,359	5,246	-2,113	-28.7%
Brookhaven National Laboratory	568	2,239	7,775	+5,536	+247.2%
Total, Chicago Operations Office	11,460	9,598	13,021	+3,423	+35.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	2,400	4,854	6,133	+1,279	+26.3%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	7,387	6,808	2,106	-4,702	-69.1%
Subtotal, Multiprogram Energy Laboratories - Facilities Support	21,247	21,260	21,260	0	0.0%
Use of Prior Year Balances	-336[a]	-13[a]	0	+13	+100.0%
Total, Multiprogram Energy Laboratories - Facilities Support	20,911	21,247	21,260	+13	+0.1%

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

Site Description

Argonne National Laboratory - East

Argonne National Laboratory - East (ANL-E) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. The laboratory consists of 122 facilities, 4.6 million gross square feet of space, with the average age of the facilities being 30 years. Approximately 29 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-03 - Electrical Systems Upgrade, Phase III (TEC $7,620,000) Project includes upgrading transmission lines, transformers, switchgear, etc. to insure system reliability.

- MEL-001-06 - Central Supply Facility (TEC $5,900,000) - This project will consolidate operations currently dispersed throughout the site into one central location.

- MEL-001-09 Fire Safety Improvements, Phase IV (TEC $8,430,000) This proposed new start for FY 2000 will bring 30 major facilities into compliance with the Life Safety Code and the National Fire Alarm Code.

The program also provides funding for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The laboratory consists of 349 facilities, 4.1 million gross square feet of space, with the average age of the facilities being 38 years. Approximately 27 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding:

- MEL-001-04 - Electrical Systems Modifications, Phase I (TEC $5,730,000) This project will include: the replacement of and installation of new cables and underground ductbanks; the installation of a new 13.8 kV - 2.4 kV substation and replacement of other obsolete components.

- MEL-001-07 - Sanitary System Modifications, Phase III (TEC $6,500,000) This project will: replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping; replace the sewage digester; connect five facilities to the sanitary system; and make other modifications to reduce discharges to the environment.

The program also provides funding for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus branch of the University of California. The laboratory consists of 118 facilities, 1.6 million gross square feet of space, with the average age of the facilities being 34 years. Approximately 19 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- MEL-001-05 - Building 77-Rehabilitation of Building Structure and Systems (TEC $8,000,000) This project will correct seismic deficiencies and refurbish and upgrade the electrical and mechanical systems to facilitate the high precision processes currently being performed in the facility.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The laboratory consists of 466 facilities, 3.4 million gross square feet of space, with the average age of the facilities being 36 years. Approximately 18 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- 94-E-363- Roofing Improvements (TEC $16,000,000) This project is replacing the roofs on numerous facilities, thereby extending their lives significantly.

- MEL-001-08 Electrical Systems Upgrade (TEC $5,900,000) This proposed new start for FY 2000 will include: replacing overhead feeders; installing advanced protective relaying capabilities at major substations; and replacing major switchgear and transformers.

Multiprogram Energy Laboratories - Facilities Support

Mission Supporting Goals and Objectives

This subprogram supports the program's goal to ensure that the multiprogram laboratories' support facilities can meet the Department's research needs primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure. General purpose facilities are general use, service and support facilities such as administrative space, cafeterias, general office/laboratory space, utility systems, sanitary sewers, roads, etc. Less than half of the space is considered fully adequate, while the remainder needs rehabilitation or replacement/demolition. The large percentage of inadequate space reflects the age of the facilities (average age of 33 years), changing research needs that require more office space and light laboratory space, ES&H requirements and obsolete systems.

Capital investment requirements are identified in laboratory Institutional Plans which address needs through the year 2003 based on expected programmatic support. The projected needs through the period total over $320,000,000. Of this amount, 53 percent is to rehabilitate or replace buildings; 33 percent is for utility projects; and 14 percent for ES&H projects. All projects are first ranked using a prioritization model that takes into account risk, impacts, and mission need. The projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Purpose Facilities	10,829	10,271	15,500	+5,229	+50.9%
ES&H	10,418	9,829	4,600	-5,229	-53.2%
Infrastructure Support	0	1,160	1,160	0	0.0%
Total, Multiprogram Energy Laboratories-Facilities Support	21,247	21,260	21,260	0	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
General Purpose Facilities			
■ Supports the initiation of one new General Purpose Facility subproject in FY 2000, as well as the continuation of three FY 1999 subprojects under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2000 new start is for design activities on the Electrical Systems Upgrade at ORNL ($357,000). The FY 1999 subprojects are the Central Supply Facility at ANL-E ($3,380,000); the Electrical Systems Modifications, Phase I at BNL ($3,881,000), and the Rehabilitation of Building 77 at LBNL ($6,133,000). Also supports the ongoing Roofing Improvements Project at ORNL ($1,749,000) (94-E-363) .	10,829	10,271	15,500
ES&H			
■ Supports the initiation of one new ES&H subproject in FY 2000, as well as the continuation of one FY 1998 and one FY 1999 subproject under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2000 new start is for design activities on the Fire Safety Improvements, Phase IV at ANL-E ($400,000). The FY 1999 subproject is the Sanitary System Modifications, Phase III at BNL ($3,000,000). Also supports the completion of the Electrical Systems Upgrade, Phase III at ANL-E ($1,200,000).	10,418	9,829	4,600
Infrastructure Support			
■ Continue meeting payments in lieu of taxes assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East.	0	1,160	1,160
Total, Multiprogram Energy Laboratories - Facilities Support	21,247	21,260	21,260

Explanation of Changes

	FY 2000 vs. FY 1999 ($000)
■ There are no changes from FY 1999 to FY 2000 for the MEL-FS program.	0
Total Funding Change, Multiprogram Energy Laboratories - Facilities Support . . .	0

Capital Operating Expenses & Construction Summary

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Unapprop. Balance
MEL-001 Multiprogram Energy Laboratories Infrastructure Project	N/A	N/A	7,259	14,924	18,351	19,346
94-E-363 Roofing Improvements, ORNL . .	16,000	5,422	3,921	4,908	1,749	0
Total, Construction		5,422	11,180	19,832	20,100	19,346

MEL-001 — Multiprogram Energy Laboratories, Infrastructure Project, Various Locations

(Changes from FY 1999 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

Two new starts in FY 2000 include: Electrical Systems Upgrade, Oak Ridge National Laboratory, and Fire Safety Improvements, Phase IV, Argonne National Laboratory-East.

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		

N/A -- See subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design and Construction			
FY 1998	7,259	7,259	2,358
FY 1999	14,924	14,924	8,955
FY 2000	18,351	18,351	18,782
FY 2001	17,316	17,316	21,210
FY 2002	2,030	2,030	8,205
FY 2003	0	0	370

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects to correct ES&H deficiencies including fire safety improvements, sanitary system upgrades and electrical system replacements; and
- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads.

General Purpose Facility Projects:

a. Subproject 01 - Upgrade Steam Plant, ORNL

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,300	0	3,400	1,900	0	0	1Q 1998 - 4Q 1999

This project will upgrade the ORNL steam plant by adding a new steam boiler of approximately 100,000 pounds per hour capacity and capable of burning both natural gas and fuel oil. The boiler will be procured with all necessary ancillary equipment, such as blowers, feedwater pumps, and controls. Suitable weather protection will be provided.

This project is needed because of the age of the five existing boilers. Three are 46 years old, one is 44 years old, and the fifth is 32 years old. The new boiler capacity will allow decreased firing time on the oldest boilers and will extend their useful life. In addition, the new boiler will improve the efficiency of the steam plant.

b. Subproject 04 - Electrical Systems Modifications, Phase I (BNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,730	0	0	849	3,881	1,000	2Q 1999 - 4Q 2001

This project is the first phase of a planned modernization and refurbishment of the Laboratory's electrical infrastructure. The project provides for the replacement of 30 to 50 year old deteriorating underground electrical cables, the addition of underground ductbanks to replace damaged portions and support new cabling, the installation of a new 13.8 kV - 2.4 kV substation to address capacity and operational problems, and the retrofitting/reconditioning of switchgear power circuit breakers.

c. Subproject 05 - Bldg. 77 - Rehabilitation of Building Structure and Systems (LBNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
8,000	0	0	754	6,133	1,113	2Q 1999 - 4Q 2001

This project will rehabilitate Building 77's structural system to restore lateral force resistance and arrest differential foundation settlement, and will modernize architectural, mechanical, and electrical systems. These upgrades will restore this 33 year-old, 68,000 sq.ft. building to acceptable seismic performance; provide environmental controls appropriate to precision fabrication processes; increase the reliability and maintainability of building systems; provide flexibility to meet future challenges; and extend building life by 40 years and building systems by 20 to 25 years.

d. Subproject 06 - Central Supply Facility (ANL-E)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,900	0	0	1,860	3,380	660	2Q 1999 - 2Q 2001

This project is a change in scope from the stand-alone facility of 39,100 sq.ft. described in the FY 1999 President's Request. The proposed facility is a 22,000 sq.ft. addition to the Transportation and Grounds Facility (Bldg. 46) along with remodeling of 3,500 sq.ft. of space in the existing Transportation and Grounds Facility. This project will result in economies and efficiencies by providing a highly efficient and cost-effective consolidated facility to meet the missions of the Materials Group and the Property Group of ANL-East and will eliminate the need for 89,630 square feet of substandard (50 year-old) space in six buildings which will be demolished (Bldgs. 4, 5, 6, 26, 27, and 28). The Materials Group receives, sorts, stores, retrieves, and distributes the majority of all materials and supplies for the Laboratory. The Property Group tags, controls, stores, and distributes excess property and precious metals for the Laboratory. This facility will contain truck docks; receiving and distribution areas; inventory control; general material storage; support and office areas; property storage; and exterior hazardous storage. This project will also eliminate 7,000 linear feet of steam supply and return lines. This proposed scope change is a result of: process improvements that have led to a reduction in on-hand inventory, relocation of DOE records storage to off-site archives; relocation of mail services; and a reduction to the labs vehicular fleet that reduced the utilization of Bldg. 46.

e. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,900	0	0	0	357	5,543	3Q 2000 - 2Q 2002

This project will replace electrical distribution feeders and upgrade transformers and switchgear feeding research facilities and primary utility support facilities throughout the Oak Ridge National Laboratory (ORNL) complex. It will also provide advanced protective relaying and metering capabilities at major substations. The project is part of a phased infrastructure upgrade to restore the electrical distribution systems serving the ORNL. The purpose of the upgrade is to maintain a reliable source of electrical power appropriate for servicing scientific research facilities. Without the proposed upgrade, the potential for electrical faults and outages will increase as the distribution system ages, with attendant increased risk of equipment damage and the potential inability to meet laboratory programmatic goals due to downtime of critical facilities. These facilities include the central research facilities, supercomputing facility, Robotics and Process Systems facility, the central chilled water plant, and the steam plant. Also, maintenance costs involved in continued operation of the existing deteriorated system will increase as the system ages.

ES&H Projects:

a. Subproject 02 - Electrical Systems Rehab. Phase IV, (LBNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
6,500	0	2,400	4,100	0	0	2Q 1998 - 4Q 2000

The Blackberry Switching Station Replacement Project is the last major planned rehabilitation to the LBNL electrical power system, in order to maintain its reliability and improve its safety. The project will upgrade the existing 12 kV power system and utilize circuit breakers installed in the FY 1987 MEL-FS project improvement to the main Grizzly Substation.

The project will correct existing deficiencies in the power distribution system that serves the Blackberry Canyon Service Area. The improvements will replace the existing electrical system, which consists of aged and underrated electrical equipment, 20 to 30 years old in many instances, that is difficult to maintain and unsafe to operate. It will provide the Laboratory with increased operational flexibility as well as improvements in reliability, maintainability and safety.

b. Subproject 03 - Electrical Systems Upgrade, Phase III, (ANL-E)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
7,620	0	1,459	4,961	1,200	0	2Q 1998 - 1Q 2001

The project provides for the upgrade of the main electrical substation at Facility 543 and Facility 549A.

The work consists of the following items: install a new 138 kV overhead steel pole transmission line and upgrade the existing transmission line, relocate an existing transformer, upgrade existing transformers, replace existing 13.2 kV outdoor switchgear, and replace existing oil circuit breaker.

The intended project will accomplish several objectives related to system reliability, personnel safety, environmental hazards, risk reduction and system expansion.

c. Subproject 07 - Sanitary System Modifications, Phase III, (BNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
6,500	0	0	500	3,000	3,000	2Q 1999 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping which collects sanitary waste from nearly all the BNL facilities. The collection piping transports the waste via gravity piping and lift stations to a sewage treatment plant (STP). This project is the third phase of the upgrade of the Laboratory sanitary waste system. In the first two phases, major operations of the STP were upgraded and approximately 14,000 feet of trunk sewer lines were replaced, repaired, or lined. Phase III will continue this upgrade and will replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping, connect five facilities to the sanitary system by installing 7,500 feet of new sewer pipe, and two new lift stations. This will eliminate non-compliant leaching fields and cess pools, reduce non-contact cooling water flow into the sewage system by 72 million gallons per year by: diverting flow to the storm system; converting water heat exchangers to air cooled condensers; and replacing water cooled equipment in 15 buildings. The STP anaerobic sludge digester will be replaced with an aerobic sludge digester to eliminate high maintenance activity and improve performance, and install liners and modify the under drain piping in the STP sand filter beds.

d. Subproject 09 - Fire Safety Improvements, Phase IV, (ANL-E)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
8,430	0	0	0	400	8,030	3Q 2000 - 2Q 2003

This project will complete the effort of correcting known deficiencies with respect to fire detection and alarm systems; life safety and OSHA related sprinkler systems; and critical means of egress in twenty-eight (28) buildings at the Argonne National Laboratory-East (ANL-E) site. Correction of these deficiencies is required to comply with DOE Order 420.1, OSHA 1910,164, and OSHA Subpart C. These deficiencies, if uncorrected, could result in unmitigated risks of injury to personnel and/or damage to DOE property in case of fire.

4. Details of Cost Estimate

N/A

5. Method of Performance

Design will be negotiated by architect-engineer contracts or laboratory personnel. To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

6. Schedule of Project Funding

N/A

7. Related Annual Funding Requirements

N/A

94-E-363 — Roofing Improvements, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 1999 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1994 Budget Request *(Preliminary Estimate)*	1Q 1994	1Q 1995	2Q 1994	1Q 1997	16,000	16,132
FY 1996 Budget Request	1Q 1994	1Q 1995	2Q 1994	2Q 2000	16,000	16,132
FY 1998 Budget Request	1Q 1994	1Q 1995	2Q 1994	2Q 2001	16,000	16,132
FY 2000 Budget Request *(Current Baseline Estimate)*	1Q 1994	1Q 1995	2Q 1994	2Q 2001	16,000	16,132

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design and Construction			
FY 1993	4,024	0 [a]	0
FY 1994	3,300	3,136 [b]	75
FY 1995	3,000	197 [c]	2,463
FY 1996	2,089	2,089	1,431
FY 1997	0	0	918
FY 1998	3,987	3,921 [d]	2,324
FY 1999	4,908	4,908	4,200
FY 2000	1,749	1,749	3,820
FY 2001	0	0	769

a This project was proposed as an FY 1993 new start (93-E-329). Application of a portion (-$4,024,000) of the FY 1993 programmatic general reduction of $40,000,000 necessitated a delay in the start of this project to FY 1994.

b Reflects reductions as follows: $-68,000 Contractor Salary Freeze; $-96,000 rescission.

c Reflects application of a portion ($-2,803,000) of Energy Supply Research and Development reductions.

d Reflects application of a portion ($66,000) of Science general reduction.

3. Project Description, Justification and Scope

This project will replace deteriorated roofing on buildings and facilities throughout the Oak Ridge National Laboratory complex. ORNL has over 2.4 million square feet of roof area on approximately 160 buildings. Based on a recent study by the laboratory's Plant and Equipment Division, approximately seventy percent of the total area needs to be replaced due to age and deterioration. This project is the first of several planned projects to replace the deteriorated roofing. It will replace the roofs that are in the worst condition (top priority) on buildings housing the most important facilities. Most of the existing roofing materials contain asbestos and much of it has traces of radioactive contaminants. This project will provide for the installation of new roofing and includes the necessary engineered controls to assure compliance with applicable health and safety regulations.

Approximately 70 percent of the roofs have been in service for over 20 years. Because of age and deterioration, many of these roofs have already developed leaks and require an increasing amount of maintenance. The results of the Plant and Equipment Division study of these roofs, giving the type and condition of each roof by building, including conditions of asbestos and/or radioactive contamination, were used as the basis of the conceptual design. In some cases the problems have reached the point that they could affect equipment, records, and research activities, as well as the health and safety of personnel working in the buildings or facilities.

During the past few years budget constraints and the increased cost of satisfying environment, safety and health regulations have resulted in a reduction in funds available for roof replacement. The effects of this shortfall have been compounded by the increased cost associated with restrictions placed on work with or around asbestos materials. Most of the roofs needing replacement involve asbestos materials. This combination of factors has resulted in a growing backlog of roofs that need replacement due to a lack of adequate funding. The current average annual cost of roof repairs is $800,000. This does not include damage from leaks before repairs are made. There is currently a backlog of over $5,000,000 of repairs needed. The roof replacement program is normally funded from expense funds; however, line item funding is requested because of the magnitude of the backlog and the need to provide an acceptable margin of response to meeting future replacement needs in a timely manner.

Failure to fund this project will result in a continuation of the expensive piece-meal repair program. As the roofs age, the number of leaks will increase, repairs will become more expensive and the potential for serious structural and equipment damage will grow, along with the threat to employee health and safety. Further deterioration of facilities could result in decreased program funding for DOE and ORNL.

Use of the metric system of measurement for design, procurement and construction of this project was considered; but because of the nature of the work and the prevailing practices in the region, it was determined to be uneconomical.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Engineering design inspection and administration of construction costs		
Engineering, design and inspection at approximately 7% of construction costs	800	800
Construction management at approximately 12% of construction costs	1,300	1,300
Project management costs at approximately 2% of engineering, design and inspection costs and construction management costs	200	200
Total, Engineering design inspection and administration of construction costs	2,300	2,300
Construction Costs (install new roofing) [b]	2,860	2,860
Removal and packaging of existing roofing	8,040	8,040
Design and project liason, testing, checkout and acceptance	200	200
Total, Construction Costs	13,400	13,400
Contingencies at approximately 19 percent of above costs	2,600	2,600
Total line item cost (TEC)	16,000	16,000

5. Method of Performance

Design shall be performed under a negotiated architect-engineer contract and inspection shall be performed by the operating contractor. To the extent feasible, construction and procurement shall be accomplished by fixed-price contracts and subcontracts awarded on the basis of competitive bidding.

a The cost estimate is based on conceptual design completed April 1991 at a cost of $70,000 and updated March 1993. The DOE Headquarters Economic Escalation Indices for Construction Projects were used as appropriate over the project cycle.

b Construction costs include $60,000 for readiness reviews.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 1998	FY 1999	FY 2000	Outyears	Total
Project cost						
Facility Cost						
Line Item TEC	4,887	2,324	4,200	3,820	769	16,000
Other Project Costs						
Conceptual design cost	70	0	0	0	0	70
Site characterization	7	0	0	0	0	7
NEPA documentation	5	0	0	0	0	5
Other project-related costs	50	0	0	0	0	50
Total, Other project costs	132	0	0	0	0	132
Total Project Cost (TPC)	5,019	2,324	4,200	3,820	769	16,132

7. Related Annual Funding Requirements

(dollars in thousands)

	Current Estimate	Previous Estimate
Facility maintenance and repair costs [a]	515	515
Total related annual funding	515	515
Total operating costs (from FY 2001 through FY 2021)	515	515

[a] Includes dollars to repair roofing installed by this project over the estimated 20 years of life.

Energy Research Analyses

Program Mission

The mission of the Energy Research Analyses (ERA) program is to evaluate the quality and impact of Department of Energy research programs and projects.

Program Goal

Provide Department of Energy program managers and senior managers with objective assessments of research projects and programs in order to evaluate the quality and impact of these efforts, to identify undesirable duplications and gaps, and to provide analysis of key technical issues in support of long range energy research planning, science and technology planning, and technical and performance evaluation of departmental programs and objectives.

Program Objectives

- *To Provide The Basis For Judgments on The Quality of Research And Its Impact*. Using merit review with peer evaluation, provide departmental program managers and their superiors with detailed information about the technical strengths and weaknesses of projects that comprise the research and development (R&D) program as a basis for judgment of the quality of the research and its impact.

- *To Provide Independent Views of Future R&D Needs in Areas of Interest to The Department*. Evaluate the status of science and technology areas of potential importance to the Department's mission, and to lay out appropriate fundamental and applied research and development to hasten the advance towards potential energy applications.

- *To Develop Strategic And Performance Plans*. Use advice from outside experts, advisory committees, departmental managers, national laboratory managers, industrial scientists and managers, and officials of other government agencies to formulate strategic and performance plans for the Office of Science and for the Science and Technology business line of the Department.

- *To Contribute to DOE And Interagency Program Analysis And Planning For Government Science And Technology*. Participate in committees, task forces, working groups, and workshops of the Department of Energy and organizations such as the National Science and Technology Council, the National Science Foundation, the National Academy of Sciences, and private sector organizations such as the Industrial Research Institute, and the Electric Power Research Institute.

Performance Measures

- Quality and value of peer review evaluations, as indicated by satisfaction of investigators and program managers and actions taken to improve or replace projects that have significant shortcomings, and to capitalize on the strengths of stronger projects.

- Satisfaction by customer program managers with assessments of science and technology needs, as indicated by changes or additions to make DOE programs and projects more productive and relevant to DOE missions.

- Quality and acceptance of strategic and performance plans, as indicated by their use by the Director of the Office of Science and by program offices in multi-year program planning, program management, and in effectively justifying programs.

- Influence on government science and technology planning and analysis, as indicated by contributions to DOE, interagency, and outside recommendations on science policies and plans.

Significant Accomplishments and Program Shifts

Energy Research Analyses

- Independent peer reviews verified the quality and relevance of over 100 DOE projects and tasks in FY 1997. These levels of effort will be scaled down through FY 2000 to accommodate the reduced funding.

- A new Office of Science Strategic Plan will be completed in FY 1999 that will guide the Office of Science into the first quarter of the next century.

- A Department of Energy Science Facilities Roadmap will be completed in FY 1999 that will optimize the Nation's investments in the Department's scientific facilities into the first quarter of the next century.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Energy Research Analyses					
Energy Research Analyses	1,434	1,000	0	1,000	1,000
Use of Prior Year Balances	-144 [1]	-92 [a]	0	-92 [a]	0
Total, Energy Research Analyses	1,290 [2]	908	0	908	1,000

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Oak Ridge Operations Office					
Oak Ridge National Laboratory	665	400	400	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	100	0	0	0	0.0%
Richland Operations Office					
Pacific Northwest National Laboratory	0	350	250	-100	-28.6%
All Other Sites [3]	669	250	350	+100	+40.0%
Subtotal, Energy Research Analyses	1,434	1,000	1,000	0	0.0%
Use of Prior Year Balances	-144[a]	-92 [a]	0	+92 [a]	+100.0%
Total, Energy Research Analyses	1,290	908	1,000	+92	+10.1%

Public Law Authorization:

Public Law 95-91, “Department of Energy Organization Act”

[1] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[2] Excludes $36,000 which has been transferred to the SBIR program and $2,000 which has been transferred to the STTR program.

[3] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

Site Description

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge Tennessee. Oak Ridge National Laboratory supports the Energy Research Analyses program in technical reviews of Department research programs. This activity includes technical support for peer review assessments and other studies and workshops as requested.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a Multiprogram Laboratory located on a 640 acre site at the Department's Hanford site in Richland, Washington. Pacific Northwest National Laboratory carries out research in the areas of technical planning and economic analysis to contribute to the Energy Research Analyses program's formulation of long term plans and science policy. This activity includes assessments of international basic energy science programs and private sector investments in energy R&D.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. This activity contributes to the Energy Research Analyses program's formulation of long-term plans and science policy.

All Other Sites

This line includes funding of research awaiting distribution pending finalization of program office detailed planning.

Energy Research Analyses

Mission Supporting Goals and Objectives

The Energy Research Analyses (ERA) program assesses research projects and programs in order to judge the significance of these efforts and to identify undesirable duplications and gaps. Peer reviews of individual research projects using outside experts are performed. Technical assessments to determine the direction of future research and state-of-the-science reviews are also performed. The program also provides analyses in support of long range energy research planning, science and technology planning, and technical evaluation of DOE programs and objectives.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Energy Research Analyses	1,434	973	973	0	0.0%
SBIR/STTR	0	27	27	0	0.0%
Total, Energy Research Analyses	1,434	1,000	1,000	0	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Energy Research Analyses			
■ Evaluate the quality and relevance of research projects in Science, Fossil Energy, and Energy Efficiency by independent peer reviews and assess additional technical needs in Science, Fossil Energy, and Energy Efficiency (e.g., advanced composite materials). Evaluate critical planning and policy issues of DOE science and technology through reviews by expert groups outside the Department such as the National Academy of Sciences and the JASON group.	1,434	973	973
SBIR/STTR			
■ In FY 1998, $36,000 and $2,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	27	27
Total, Energy Research Analyses	1,434	1,000	1,000

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ There are no funding changes from FY 1999 to FY 2000 for Energy Research Analyses.	0
Total Funding Change, Energy Research Analyses	0

Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences program is a broad-based, fundamental research effort, producing valuable scientific knowledge and technological benefits in the near term with the aim of providing the science base for a fusion energy option in the long term.

This is a time of important progress and discovery in fusion research. By virtue of previous investments in facilities, and more recently, sophisticated diagnostics and modeling capabilities, the Fusion Energy Sciences program is making great progress in understanding the fundamental processes of confining fusion fuels, such as the mechanisms responsible for turbulent losses of particles and energy across the magnetic field lines. In addition, the program is identifying and exploring innovative approaches to fusion power in search of an optimized confinement system with an affordable development path.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

The goal of the Fusion Energy Sciences program is to:

> *"Acquire the knowledge base for an economically and environmentally attractive fusion energy source."*

Although there is not a schedule for developing and deploying fusion energy systems the availability of fusion, as an option for large central station power plants, would be valuable insurance against possible environmental concerns about fossil and nuclear energy. In addition, there may be nearer term non-electric applications of fusion in transmutation of wastes and isotope production.

Program Objectives

Crosscutting and interrelated objectives of the Fusion Energy Sciences program, as developed through stakeholder meetings and endorsed by the Fusion Energy Sciences Advisory Committee, are summarized below.

- *Understand the physics of plasmas, the fourth state of matter*. Plasmas comprise most of the visible universe, both stellar and interstellar, and have many practical applications. Progress in plasma physics has been the prime engine driving progress in fusion research, and conversely, fusion energy has been the dominant motivation for plasma physics research.
- *Identify and explore innovative and cost-effective development paths to fusion energy*. There are several approaches to fusion, from the tokamak, which is the most advanced power plant candidate, to alternative magnetic configurations, or to inertial confinement using particle beams or lasers. The

current fusion program includes research on tokamak improvements and, increasingly, research on other innovative concepts, including drivers for inertial fusion energy.

- *Explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in an international effort*. Understanding the physics of energy-producing (i.e. burning), plasmas and developing the technologies essential for fusion energy are linked goals that can best be achieved through the cooperative efforts of the world community. The long-term benefits to the United States in such a cooperative effort include enhanced progress toward our mission through scientific and technological integration in the much larger world fusion effort as an energy source for a growing world population.

The Fusion Energy Sciences budget is divided into three subprograms; Science, Facility Operations, and Enabling R&D. The Science subprogram includes research funds for plasma science and the development of improved confinement concepts. Funds for building and operating major experimental facilities are in the Facility Operations subprogram. The Enabling R&D subprogram includes funds for establishing the scientific foundation which underlies current advances in fusion technology and provides technological capabilities and innovations needed to advance plasma science and develop the knowledge base for an attractive fusion energy source.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $96,600,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for thousands of scientists in universities, and other Federal laboratories. It will also leverage both Federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will support operations at the Department's three major fusion energy physics facilities: the Doublet III-D at General Atomics, the Alcator C-Mod at the Massachusetts Institute of Technology and the National Spherical Torus Experiment at Princeton Plasma Physics Laboratory.

Performance Measures

The Fusion Energy Sciences program supports the Department's strategic goal of delivering the scientific and technological innovations critical to meeting the Nation's energy challenges. The performance measures of the Fusion Energy Sciences program fall into four areas: (1) excellence of the science, (2) relevance to the DOE mission and national needs, (3) stewardship of research capabilities, and (4) human resource management. The ways in which the Fusion Energy Sciences program measures performance include components such as peer review, specific charges to the Fusion Energy Sciences Advisory Committee (FESAC), and professional recognition of research performers. These have been an integral part of the program for many years. Each major research facility has a Program Advisory Committee (PAC) that provides broadly based community input directly to the facility team. Proposals for new facilities or upgrades to existing facilities at laboratories have both scientific and cost and schedule reviews.

For FY 2000, specific performance measures are:

- The National Spherical Torus Experiment (NSTX) will operate with a National Research Team demonstrating long pulse (greater than 1 second) operation at plasma currents approaching 1 megampere, a factor of 40 increase over the current exploratory level spherical torus experiments.
- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- The DIII-D tokamak will test the feasibility of using increased electron cyclotron heating power and improved power exhaust techniques to extend the pulse length of advanced toroidal operating modes, a necessary requirement for future fusion energy sources.
- A decontamination and decommissioning contract at the Princeton Plasma Physics Laboratory (PPPL) will be awarded for the removal of the Tokamak Fusion Test Reactor (TFTR) tokamak and activated components from the experimental test cell.
- The materials research program will be coordinated with design studies through an overall systems approach, and broadened to allow increased modeling and innovative exploratory research on novel materials" as recommended by the FY 1998 FESAC materials review.
- New funding opportunities in basic plasma science and junior plasma physics faculty development programs will be provided through competitive announcements.
- The theory of strong turbulence will be used as a foundation to develop models for using shear in the plasma flow to stabilize the transport of energy and particles in toroidal devices such as tokamaks and stellarators. In addition, a new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Significant Accomplishments and Program Shifts

Science

- To accommodate continuing governmental financial constraints, the fusion sciences program continues to move toward more innovation and increased understanding of a wider range of confinement concepts, and away from the more costly, large scale devices aimed at providing integrated plasma and technology experiments operating with power plant-scale plasma parameters.
  - Support of the goal to understand the physics of plasmas continues at the increased level of funding for general plasma science to improve the basis for fusion science and research on high-temperature toroidal plasmas in the DIII-D, C-MOD, and NSTX experiments.
  - Support of the goal to explore innovative and more affordable development paths includes increased operation of the new NSTX science facility. Work on concept improvement at the exploratory level in both physics and enabling R&D will continue to receive strong emphasis.
- A major review of magnetic and inertial fusion energy options by the Secretary of Energy Advisory Board has begun in FY 1999 in response to congressional requests.

- The National Academy Review of the Quality of Science in the Fusion Energy Sciences Program will be carried out in FY 1999 as part of a follow-up to the 1996 restructuring of the fusion program.
- A review of leading candidates for the next proof-of-principle steps within the innovative confinement concepts program was carried out, and program recommendations will be made by FESAC in FY 1999.
- In FY 1999 scientists at the University of Wisconsin will begin testing new stellarator symmetry principles which promise to improve understanding of how to optimize this toroidal fusion concept. At the Lawrence Livermore National Laboratory the first experiments on high temperature sustainment of spheromak plasmas will begin. Both of these elements represent initial results from the FY 1996 restructuring of the fusion program to work more on innovative confinement concepts.
- Within the NSF/DOE Partnership in Basic Plasma Science and Engineering begun in FY 1997, an additional set of applications were reviewed in FY 1998, and 13 were selected for funding including two NSF Career awards. Of the successful applicants, 7 were funded directly by OFES and funding was shared for one of the NSF Career awards. The fusion-sponsored development program for junior faculty in plasma physics in FY 1998 resulted in 2 additional awards. Both programs will continue in FY 1999 and planning with other agencies, including NSF, will be carried out for FY 2000 initiatives.
- A peer-reviewed competition for new ideas in measurement techniques for toroidal and burning plasma devices was carried out in early FY 1999 and awards were announced in February 1999.
- The Electron-Impact Ionization Theory, which was developed at the National Institute of Standards and Technology for fusion applications, is beginning to find application in modeling for air pollution control devices and ionization and radiation monitors. Its application to modeling for plasma processing of semiconducting devices by INTEL and other companies, which was reported last year, continues to grow.
- Current drive using new microwave hardware was shown for high magnetic field operation of the Alcator C-Mod facility. These results, along with demonstrated microwave heating at high magnetic field, indicate that advanced toroidal operating modes can be produced and studied in Alcator C-Mod.

Facility Operations

- The National Spherical Torus Experimental (NSTX) project at the Princeton Plasma Physics Laboratory (PPPL) will be completed in FY 1999 and a national research team will be organized. The facility will begin experimental operations by the 3rd quarter of FY 1999 and the NSTX Program Advisory Committee (PAC) will provide guidance to PPPL for initial operations.
- Significant modifications to the divertor and heating systems of the DIII-D facility were completed, providing capabilities required for FY 2000 experiments that will extend the pulse duration of advanced toroidal operating modes. Important experimental results were obtained that show plasma stability control with feedback coils and demonstration of radio frequency current drive that is necessary for long pulse operations.

Enabling R&D

- Support of the goal to explore the science and technology of energy producing plasmas is dramatically reduced by termination in FY 1999 of U.S. participation in the international pursuit of leading edge science in an integrated, large-scale experimental facility (ITER).
- In early FY 1999, the U.S. will close out its participation in ITER design activities.
- In FY 1999, we will work with other ITER Parties to attempt to complete the testing of the ITER superconducting model coil in Japan. This testing program will confirm the design and establish operating margins and will allow us to benefit from the $45,000,000 we have invested in building a major portion of the coil.
- The fusion program will continue its bilateral and multilateral activities on major scientific facilities abroad and maintain observer contact with the ITER project to keep informed of progress by the remaining three ITER parties.
- The program will retain low activation materials research. However, remaining enabling R&D activities supporting energy-producing plasmas will be drastically reduced.
- A series of critical enabling R&D tasks involving radio-frequency heating and current drive components were successfully completed over the past year. Tasks include fabrication of the NSTX antenna and tuning system, and installation of a DIII-D high power microwave system. The results of these auxiliary heating development efforts will have broad applicability to future U.S. fusion experiments.
- AWARDS

  Marshall Rosenbluth, University of California at San Diego, was awarded the **National Medal of Science** in December 1997

  Darin Ernst, Princeton Plasma Physics Laboratory, won the **1998 APS-DPP Award for Outstanding Doctoral Dissertation in Plasma Physics**

  Nine fusion researchers were elected **Fellows of the American Physical Society in 1998**

  Paul Woskov, MIT Plasma Science and Fusion Center, in collaboration with PNNL, won a **1998 R&D 100 Award** for a device that measures smokestack emissions. The award winning work has its roots in fusion diagnostics and plasma physics.

Funding of Contractor Security Clearances

- In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $115,000 and $96,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Funding Profile

	(dollars in thousands)				
	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Fusion Energy Sciences					
Science	95,116	118,982	-664	118,318	125,434
Facility Operations	56,149	61,195	0	61,195	69,380
Enabling R&D	66,025	43,123	0	43,123	27,800
Program Direction	6,900	0	0	0	0
Subtotal, Fusion Energy Sciences	224,190	223,300	-664	222,636	222,614
General Reduction	0	-664	+664	0	0
Use of Prior Year Balances	-791 [a]	-1,136 [b]	0	-1,136 [b]	0
Total, Fusion Energy Sciences	223,399 [c]	221,500	0	221,500	222,614

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

[a] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[c] Excludes $5,157,000 which has been transferred to the SBIR program and $309,000 which has been transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	4,143	4,219	4,419	+200	+4.7%
Sandia National Laboratories	5,850	4,115	3,565	-550	-13.4%
Total, Albuquerque Operations Office	9,993	8,334	7,984	-350	-4.2%
Chicago Operations Office					
Argonne National Laboratory	2,835	2,540	2,135	-405	-15.9%
Brookhaven National Laboratory	50	0	0	0	0.0%
Princeton Plasma Physics Laboratory	49,612	50,332	58,979	+8,647	+17.2%
Total, Chicago Operations Office	52,497	52,872	61,114	+8,242	+15.6%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	4,120	1,740	1,000	-740	-42.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,947	5,334	5,255	-79	-1.5%
Lawrence Livermore National Laboratory . . .	10,518	11,158	10,168	-990	-8.9%
Stanford Linear Accelerator Center	50	50	50	0	0.0%
Total, Oakland Operations Office	14,515	16,542	15,473	-1,069	-6.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	1,229	910	800	-110	-12.1%
Oak Ridge National Laboratory	17,870	17,480	15,866	-1,614	-9.2%
Total, Oak Ridge Operations Office	19,099	18,390	16,666	-1,724	-9.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,410	1,430	+20	+1.4%
Savannah River Operations					
Savannah River Tech Center	452	219	0	-219	-100.0%
All Other Sites [a]	122,099	123,129	118,947	-4,182	-3.4%
Subtotal, Fusion Energy Sciences	224,190	222,636	222,614	-22	0.0%
Use of Prior Year Balances	-791 [b]	-1,136 [c]	0	+1,136 [c]	+100.0%
Total, Fusion Energy Sciences	223,399	221,500	222,614	+1,114	+0.5%

[a] Funding provided to laboratories, universities, industry, other federal agencies, and other miscellaneous contractors.

[b] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[c] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Argonne's Fusion Energy Sciences program contributes to a variety of fusion enabling R&D program activities in areas of modeling, analysis, and experimental research. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices, including the ALEX facility, that studies the interaction of flowing liquid metals with magnetic fields, and liquid lithium flow loop that studies corrosion in candidate structural alloy materials. Argonne's capabilities in the engineering design of fusion energy systems has contributed to the design of ITER components, including blankets, tritium systems, and plasma-facing components, as well as to analysis supporting ARIES studies of fusion power plant concepts. Argonne also contributes to low-activation materials research with its unique capabilities in vanadium alloy testing in fission reactors and post-irradiation examinations.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Since 1978, INEEL has been the lead laboratory for fusion safety for the Fusion Energy Sciences program. As the lead laboratory, they have helped to develop the fusion safety data base which will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. They have focused their research on:
(1) understanding the behavior of the sources of radioactive and hazardous materials in a fusion machine,
(2) understanding the energy sources in a fusion machine that could mobilize these materials, and
(3) developing the analytical tools that demonstrate the environmental and safety characteristics of a fusion machine. In FY 2000, fusion efforts at INEEL will be focused solely on safety research associated with existing or planned domestic experimental facilities.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. One of LBNL's missions is to study and apply the physics of heavy ion beams and to advance related technologies. The U.S. Heavy-Ion Fusion (HIF), centered at LBNL, program has the long-range goal of developing inertial fusion energy (IFE) as an economically and environmentally attractive source of electric power.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. LLNL is host for Defense Programs' National Ignition Facility, which will give the United States the first opportunity in the world to demonstrate inertial fusion ignition and energy gain in the laboratory. This goal will provide the IFE program with crucial results concerning target physics. This fusion energy mission is consistent with the NIF mission statement. Livermore partners with other Laboratories (LBNL, for example, in Heavy Ion Fusion) in fusion energy research. This program also includes collaborations on the DIII-D tokamak at General Atomics, construction of an innovative concept experiment, The Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. The SSPX will start experimental operations in FY 1999. Definitive results on the feasibility of sustaining high temperature spheromak plasmas utilizing external electrode current drive are expected by the end of FY 2000.

Los Alamos National Laboratory

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. The FY 2000 budget will support the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetic Target Fusion, and maintenance of the Tritium Systems Test Assembly (TSTA) facility in a standby mode.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150 acre site in Oak Ridge, Tennessee. ORISE was established by DOE to undertake national and international programs in education, training, health, and the environment. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with DOE. Established in 1946, ORAU is a consortium of 88 colleges and universities. For the Office of Fusion Energy Sciences (OFES), ORISE acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with OFES, the Oak Ridge Operations Office (ORO), participating universities, DOE laboratories, and industries. ORISE also assists in the organization and administrative support for the Fusion Energy Sciences Advisory Committee meetings.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. ORNL develops a broad range of components that are critical for improving the research capability of fusion plasma experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. ORNL will provide leadership of the Virtual Laboratory for Technology, which integrates all U.S. fusion program enabling R&D activities into a coordinated multi-institutional framework. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of particles. Research is also done in the area of turbulence and its effect on transport of heat through plasma. Codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Fusion Energy Sciences program at PNNL is focused on research on materials that can survive in a fusion neutron environment. The available facilities used for this research include mechanical testing and analytical equipment, including state-of-the-art electron microscopes, that are either located in radiation shielded hot cells or have been adapted for use in evaluation of radioactive materials after exposure in fission test reactors. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper and ferritic steels as part of the U.S. fusion materials team. PNNL also plays a leadership role in a fusion materials collaboration with Japan, with Japanese owned test and analytical equipment located in PNNL facilities and used by both PNNL staff and up to ten Japanese visiting scientists per year.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. It hosts experimental facilities used by multi-institutional teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device closely related to the tokamak, and is currently working on the conceptual design of another innovative toroidal concept, the compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This work is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced 175 Ph.D. graduates since its founding in 1951.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonapah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing plasma-facing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interfaces of plasmas and fusion device first wall. Sandia selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their in use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which use high-power electron beams to stimulate high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international fusion experiments in areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC is operated for the United States Department of Energy by Stanford University. The main interest in fusion at SLAC is the possibility of adapting the accelerator science and technology from elementary particle physics to the production of fusion power from the implosion of inertial fusion targets driven by beams of high energy, heavy ions. A member of the accelerator research department at SLAC has been involved with the heavy ion fusion program since its inception.

All Other Sites

The Fusion Energy Sciences program funds research at 51 colleges/universities located in 25 states. This line also includes funding for DIII-D and related programs at General Atomics and funding of research awaiting distribution pending completion of review results or program office detailed planning.

Science

Mission Supporting Goals and Objectives

The goals of this subprogram are to advance our understanding of plasma science, and to develop innovative approaches for confining a fusion plasma. These goals are accomplished through a modest program in basic plasma science; active research programs in both toroidal innovations and in non-toroidal concepts; focused efforts to resolve outstanding physics issues related to energy producing plasmas; strong theory and modeling programs; and the creation of improved diagnostics that make possible rigorous testing of the scientific principles of fusion.

Plasma science is the study of ionized matter—ranging from neon lights to stars—that make up 99 percent of the visible universe. It contributes not only to fusion research, but also to many national science and technology goals, ranging from astrophysics to industrial processing to national security. One objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma physics. Ongoing programs including a development program for junior faculty in plasma physics and a joint NSF/DOE partnership in plasma physics and engineering contribute to this objective.

Fusion energy research advances through a balanced combination of large-, medium-, and small-scale experiments, theory, and modeling. The largest component of the Science subprogram is the tokamak research activity, which focuses on gaining a predictive understanding of the behavior of plasmas in near reactor-level conditions where the fusion fuel begins to “burn”. Tokamak research will be carried out primarily on the DIII-D facility at General Atomics. DIII-D has been a major contributor to the world fusion program over the past decade by developing advanced modes of toroidal operations through the flexibility of its plasma shaping and computer control systems, and by increasing the knowledge base of fusion physics through extensive diagnostics and theoretical and modeling support of experiments. The other major U.S. tokamak experiment, the Alcator C-Mod at the Massachusetts Institute of Technology (MIT), uses high magnetic fields to explore high temperature and density plasmas in a unique, compact, and cost-effective facility. Additional high-leverage tokamak research will be carried out through international collaborations on large, state-of-the-art facilities abroad. Increased collaboration on facilities such as JET (Europe) and JT-60 (Japan) was recommended by the Fusion Energy Science Advisory Committee.

Research on alternative confinement concepts, both magnetic and inertial, is aimed at identifying approaches that may improve the economical and environmental attractiveness of fusion energy sources. This research is carried out at various levels ranging from the concept explorations stage to the proof-of-principle stage. The first proof-of-principle experiment, the new National Spherical Torus Experiment (NSTX) facility at the Princeton Plasma Physics Laboratory (PPPL), will begin its first full year of operation in FY 2000, with a goal of demonstrating improved stability and confinement in a very compact structure over the next several years. Additional proof-of-principle level experiments at PPPL, University of Wisconsin, and Los Alamos National Laboratory have been positively reviewed and are awaiting further consideration by the Fusion Energy Sciences Advisory Committee. Small-scale exploratory experiments are carried out primarily at universities, while proof-of-principle experiments, such as the NSTX will be primarily hosted at national laboratories.

The Inertial Fusion Energy (IFE) activity is exploring an alternate path for fusion energy that would capitalize on the major R&D effort in inertial confinement fusion (ICF) carried out for stockpile stewardship purposes within the Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the physics of target ignition that will be tested in the National Ignition Facility at LLNL. Efforts in IFE focus on developing the components needed to apply the ICF results to energy systems. These include the most efficient methods for heating and compressing a target pellet to fusion conditions, methods for clearing the target chamber between pulses, and target design.

Theory and modeling are essential to progress in fusion and plasma science because they provide the capability to analyze existing experiments, produce new ideas to improve performance, and provide a scientific assessment of new ideas. An important component of the theory program is the development and use of computational tools to help understand the physical phenomena that govern confinement of high temperature plasmas. Similarly, the development and improvement of diagnostic tools for analyzing plasma behavior continues to provide new insights regarding fusion plasmas.

Performance Measures

- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- A new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Tokamak Experimental Research	46,198	46,831	45,918	-913	-1.9%
Alternative Concept Experimental Research	23,996	38,600	45,150	+6,550	+17.0%
Theory	19,773	22,500	23,000	+500	+2.2%
General Plasma Science	5,149	6,109	6,500	+391	+6.4%
SBIR/STTR	0	4,278	4,866	+588	+13.7%
Total, Science	95,116	118,318	125,434	+7,116	+6.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Tokamak Experimental Research			
■ TFTR physics research was completed in 1998.	5,500	0	0
■ DIII-D at General Atomics (GA) is the major operating tokamak in the United States. DIII-D is a national facility, with about half of its scientific staff coming from U.S. fusion laboratories other than GA, as well as some from several foreign laboratories. In FY 2000 the research activity will focus on use of two new hardware improvements in auxiliary heating and power exhaust systems. This will allow progress in the development of advanced toroidal operations for long pulses which is essential for incorporation of these operating modes into the design of future machines.	21,430	21,905	22,520
■ Alcator C-Mod will also operate as a national facility with an improved set of diagnostics. Research activity will focus on support of the compact, high field approach to ignition and on the physics of the plasma edge and power exhaust.	6,211	7,600	7,800
■ Several unique, innovative tokamak experiments are supported at leading universities. These focus on various topics, including advanced toroidal operating modes and plasma stability and control. This program also develops unique diagnostic probes that provide an understanding of the plasma behavior in fusion research devices, supplying the necessary information for analysis codes and theoretical interpretation. The requested funding level in FY 2000 supports the core diagnostic development research, as well as the work begun as a result of an FY 1999 competitive initiative to develop new diagnostic techniques.	6,557	7,400	7,250

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ International collaboration at the level of $4,200,000 provides the opportunity for joint and coordinated experiments between the U.S. and foreign experiments, thereby increasing the database and the understanding of fusion physics. With the limited operation of major tokamaks in the U.S., international collaboration provides increased opportunity for the U.S. scientists to continue their participation in the advancement of fusion science, especially in the area of burning plasma physics. The scientists from PPPL and ORNL will continue collaborations with JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe and with JT-60U in Japan. The remaining $4,148,000 is required for graduate and postgraduate fellowships in fusion science and technology, general science literacy programs with teachers and students, support for historically black colleges and universities, and similar broad outreach efforts related to fusion science and technology. . . .	6,500	9,926	8,348
Total, Tokamak Experimental Research	46,198	46,831	45,918
Alternative Concept Experimental Research			
■ **Experimental Plasma Research (Alternates):** Research on novel magnetic confinement configurations is important both for its intrinsic scientific value and for its potential to discover concepts that would make more attractive fusion power sources. This category has two components. The first component contains twelve diversified exploratory level experiments located primarily in universities. Four of these experiments (Sustained Spheromak Physics Experiment at LLNL; Columbia University/MIT Dipole; Ion Rings at Cornell University; and Ion Trap at LANL) resulted from a FY 1998 innovative concept competition. A second category includes design and experimental work on three novel concepts that have been proposed for full proof-of-principle funding..	14,550	19,000	23,750
■ **NSTX:** The NSTX at PPPL will begin the first full year of research in FY 2000. The research program will be organized as a national collaboration with representatives of other institutions participating in the research activity on an equal basis with researchers from PPPL. Initial objectives will be plasma formation, two methods of controlled startup, plasma heating by radio-frequency waves and diagnostic surveys to define acceptable operational regimes that can be used			

	FY 1998	FY 1999	FY 2000
for more powerful experiments. Advanced diagnostic development specifically for NSTX is also funded by this element.	2,446	9,800	11,300
■ **Inertial Fusion Energy:** Inertial fusion energy research continues with efforts to improve heavy ion accelerator efficiency, chamber wall protection, and design of fusion energy target pellets. Scoping studies for major next step device options will be undertaken, with a goal of providing the inertial fusion energy program the capacity to benefit from physics results on Defense Programs' National Ignition Facility in the latter part of the next decade.	7,000	9,800	10,100
Total, Alternative Concept Experimental Research	23,996	38,600	45,150

(dollars in thousands)

Theory

■ The theory and modeling program is a broad-based program with researchers located at national laboratories, universities, and industry. A new program emphasis is advanced computing, including the development of new modeling codes and a code library for use by all fusion researchers. Work in tokamak theory ($15,105,000) includes efforts to support existing toroidal experiments and also includes the development of many new theories and modeling tools, since these are usually applied to tokamaks before being applied to alternates. An example of this is work on self organized criticality, which may provide a new approach to understanding confinement. The majority of the work in toroidal theory is aimed at developing a complete physical picture of advanced toroidal operating modes. With the restructuring of the fusion program, there is an increased focus on alternate concepts. In alternate concept theory ($2,707,000), the emphasis will be on understanding the fundamental processes determining equilibrium, stability, and confinement in each alternate. Generic theory ($2,188,000) covers development of basic plasma theory that is applicable not only to fusion research, but also to basic plasma science. It also includes work on atomic theory, which is applicable to all confinement devices.

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
The objective of the advanced computing activity is to improve simulation and modeling capabilities in order to obtain a quantitative understanding of plasma behavior in fusion experiments. This will ensure optimum use of a set of innovative national experiments and fruitful collaboration on major international facilities. In FY 2000, funds ($3,000,000) will be used to develop a modern transport code to simulate energy transport in toroidal magnetic confinement systems. . .	19,773	22,500	23,000
General Plasma Science			
■ The plasma science program focuses on basic plasma science and engineering research, primarily in the university community. Advances in basic plasma physics will support the Fusion Energy Sciences program as well as other important areas of science and technology. Both the Plasma Science Junior Faculty Development Program and collaborative efforts such as the NSF/DOE plasma science and engineering program will continue at FY 1999 levels. The program will also continue to collect and distribute atomic physics data for fusion.	5,149	6,109	6,500
SBIR/STTR			
■ In FY 1998 $3,476,000 and $208,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	4,278	4,866
Total, Science	95,116	118,318	125,434

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Tokamak Experimental Research	
■ Additional funding is provided for increased diagnostics on DIII-D.	+615
■ Additional funding is provided for increased research expenses on Alcator C-Mod..	+200

	FY 2000 vs. FY 1999 ($000)
■ This decrease is primarily associated with the FY 1999 prior year general reduction account going to zero in FY 2000.	-1,578
■ Reduction will decrease support for research at UCLA	-150
Total, Tokamak Experimental Research	-913
Alternative Concept Experimental Research	
■ Support for NSTX research is increased to provide funding for personnel and minor equipment for the first full year of operations that includes research collaborations and preparations of advanced diagnostics.	+1,500
■ Funding for alternate concept experiments is increased to maintain breadth and permit establishment of one or more proof-of-principle experiments..	+4,750
■ This increase will permit continued efforts to improve accelerator efficiency for inertial fusion energy..	+300
Total, Alternative Concept Experimental Research	+6,550
Theory	
■ The advanced computational effort will expand efforts to develop new codes to predict plasma performance.	+500
General Plasma Science	
■ These funds will enhance the NSF/DOE Partnership in Basic Plasma Science and Engineering.	+391
SBIR/STTR	
■ Support for SBIR/STTR is mandated at 2.65 percent. These grants will support plasma science, fusion science, and fusion enabling R&D.	+588
Total Funding Change, Science	+7,116

Facility Operations

Mission Supporting Goals and Objectives

This activity provides for the operation of major experimental facilities that are the essential tools that enable scientists in university, industry, and laboratory based research groups to perform experimental research in fusion research facilities: DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. It includes the cost of operating personnel, electric power, expendable supplies, replacement parts and subsystems, and inventories. In the case of PPPL, this funding also supports beginning the final three-year phase of decontamination and decommissioning of the Tokamak Fusion Test Reactor which was shut down in FY 1997; ongoing caretaking for the tritium systems and activated elements is required during this process. General plant projects (GPP) funding for PPPL supports minor facility renovations, other capital alterations and additions, and buildings and utility systems. Capital equipment funding for upgrading the research capability of DIII-D is also included, as are funds for design, modification, and installation of the NSTX neutral beam heating system, and for further enhancements to the facility.

The principal objective of the Facility Operations subprogram is to maximize the quantity and quality of data collected for experiments being conducted at fusion energy science facilities.

The following table summarizes the scheduled weeks of operations for DIII-D and NSTX.

Facility Utilization

(Weeks of Operation)

	FY 1998	FY 1999	FY 2000
DIII-D	15	14	14
Alcator C-Mod	9	12	18
TFTR	8	0 [a]	0 [a]
NSTX	0	6	14

[a] Facility Shutdown.

Funding Schedule

(dollars in thousands)	FY 1998	FY 1999	FY 2000	$ Change	% Change
TFTR	5,140	3,600	13,600	+10,000	+277.8%
DIII-D	26,370	29,195	29,880	+685	+2.3%
Alcator C-Mod	9,689	9,923	10,100	+177	+1.8%
NSTX	13,850	16,800	15,000	-1,800	-10.7%
General Plant Projects /Other	1,100	1,677	800	-877	-52.3%
Total, Facility Operations	56,149	61,195	69,380	+8,185	+13.4%

Detailed Program Justification

(dollars in thousands)	FY 1998	FY 1999	FY 2000
TFTR			
■ Begin a three-year program ($10,000,000 in FY 2000 out of a planned total of $48,000,000) to complete the decontamination and decommissioning of TFTR. This activity will provide for the removal and disposal of the tokamak and remaining activated components from the test cell and the basement. In addition during the D&D funding ($3,600,000) is necessary to maintain and keep the facility safe during the project.	5,140	3,600	13,600
DIII-D			
■ Provides support for operation, maintenance, and improvement of the DIII-D Electron Cyclotron Heating (ECH) systems and support for other equipment at the GA site. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 14 weeks; plus downtime for significant upgrades to the ECH, divertor systems, and maintenance.	26,370	29,195	29,880
Alcator C-Mod			
■ Provides support for operation, maintenance and minor machine improvements. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 18 weeks; plus down time for machine and diagnostic improvements.	9,689	9,923	10,100

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
NSTX			
■ Provides for continuation of research activity on the NSTX experiment and installation of the first set of planned diagnostic upgrades. This will allow extension of the pulse duration to 1 second and operation at plasma currents approaching 1 megampere, a factor of 40 increases over current exploratory level spherical torus experiments; first investigations of non-inductive current drive, a principal program objective; and measurement of advanced plasma confinement scenarios.	1,770	7,900	12,500
■ **NSTX Project:** Project completed in FY 1999 and facility begins operations.	12,080	5,450	0
■ **NSTX Neutral Beam:** Project for preparation and installation of a previous TFTR neutral beam heating system on NSTX.	0	3,450	2,500
Total, NSTX	13,850	16,800	15,000
General Plant Projects/Other			
■ These funds provide primarily for general infrastructure repairs and upgrades. The major project included in the FY 2000 plan is an upgrade of the fire alarm system throughout the site where NSTX is located.	1,100	1,677	800
Total, Facility Operations	56,149	61,195	69,380

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
TFTR	
■ Funding is provided to initiate TFTR decontamination and decommissioning.	+10,000
DIII-D	
■ Additional funding is for operation of increased number of DIII-D systems (ECH, divertor, etc.).	+685
Alcator C-Mod	
■ Additional funding is provided for increased operation of the Alcator C-Mod.	+177
NSTX	
■ A decrease for the NSTX project at PPPL is due to the completion of fabrication, and a shift to facility operations.	-5,450
■ An increase in NSTX facility operations to support the first full year of operations.	+4,600
■ A decrease in NSTX neutral beam heating system to complete this fabrication effort.	-950
Total, NSTX	-1,800
General Plant Projects/Other	
■ General Plant Projects support at PPPL is increased $100,000 to reflect maintenance requirements; support for other facility operations is terminated.	-877
Total Funding Change, Facility Operations	+8,185

Enabling R&D

Mission Supporting Goals and Objectives

For sustained scientific progress toward ultimate research goals, science-oriented programs that push the frontiers of human knowledge, such as fusion, require intellectual resources, experimental facilities with state-of-the-art technological capabilities, and technology innovations. The Enabling R&D subprogram includes funds for: (1) establishing the scientific foundation that underlies current technological advances in fusion, and (2) providing the technological capabilities and innovations needed to advance fusion science; developing the knowledge base for an attractive fusion energy source. These contribute to two strategic goals for the fusion program. This subprogram is divided into two elements: Engineering Research and Materials Research.

For the Engineering Research element, activities through FY 1998 were heavily oriented toward the ITER Engineering Design Activities (EDA), a four party (European Union, Japan, Russian, U.S.) international effort to demonstrate the scientific and technological feasibility of fusion as an energy source. In July 1998 the other three ITER parties prepared to enter into a 3-year post-EDA extension period that would develop a reduced cost design and provide the basis for an assessment of the technical, financial, and hosting readiness to proceed with ITER construction as an international project. However the DOE was unable to obtain congressional agreement for U.S. participation in the extension. Accordingly, the U.S. effort toward ITER will be closed out in early FY 1999, and the Engineering Research element restructured by being downsized and redirected away from energy-oriented goals.

In restructuring this element in FY 1999, the scope of activities will be broadened to address more fully the diversity of domestic interests in enabling R&D. These interests include a focus on critical needs for enabling technologies for U.S. plasma experiments and for international collaborations that allow the U.S. to access plasma experimental conditions not available domestically. These interests also include the scientific foundations of innovative technology concepts for future plasma experiments. These innovations are needed to exploit the performance gains being sought from physics concept improvement research. Major FY 1998 accomplishments include: completion, as an ITER participant, of the ITER Final Design Report, which is the first comprehensive, fully integrated design of a major fusion power experiment; completion of winding the ITER superconducting magnet model coil, which will be shipped to Japan in early FY 1999 for testing in a Japanese facility during FY 1999; and completion of critical tasks involving radio-frequency heating and plasma current drive components that have broad applicability to the U.S. fusion program.

The Materials Research element continues to focus its scientific research on low-activation materials which have high performance capability and can withstand long-term exposure to the energetic particles and electromagnetic radiation expected from energy-producing plasmas. During FY 1998, this element made major inroads toward mapping of irradiation effects on candidate low-activation alloys, which is needed to set priorities for future research, and underwent a review by FESAC that will continue to influence planning for FY 1999 and beyond.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Engineering Research	58,281	34,991	20,074	-14,917	-42.6%
Materials Research	7,744	7,000	7,000	0	0.0%
SBIR/STTR	0	1,132	726	-406	-35.9%
Total, Enabling R&D	66,025	43,123	27,800	-15,323	-35.5%

Detailed Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Engineering Research			
■ Funding reductions will require a substantial downsizing and redirection of effort on the energy-oriented technology segment of the fusion program. Efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for future plasma experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components ($5,600,000) and plasma heating and fueling technologies ($3,700,000). Longer-term efforts will be oriented toward: superconducting magnet research ($1,500,000) and plasma facing and energy extraction component innovations ($1,500,000) needed to fully exploit investments in concept improvement experiments; and toward tritium research ($1,000,000) and safety research ($1,000,000) issues critical to the safety and environmental attractiveness of fusion as an energy source. Advanced design studies will be directed toward identifying attractive pathways toward fusion energy ($2,950,000). In addition, design studies of next-step options ($2,224,000), taking fullest advantage of recent scientific advances, will continue. Management of this diverse collection of fusion technologies will be accomplished through a Virtual Laboratory for Technology ($600,000) whereby improved coordination and communication of plans, progress, and results will be accomplished through the use of modern information technology.	58,281	34,991	20,074

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Materials Research			
■ Materials research remains a key element in developing a safe, reliable, and environmentally attractive fusion energy system. Scientific understanding and the development research and testing of vanadium alloys, silicon carbide composite materials, and advanced ferritic steels for structural service in the high power zones for fusion energy sources will continue. Priorities for this work, including innovative approaches to evaluating materials and improved modeling of materials behavior are guided by the results of a Fusion Energy Sciences Advisory Committee review conducted during 1998.	7,744	7,000	7,000
SBIR/STTR			
■ In FY 1998 $1,681,000 and $101,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	1,132	726
Total, Enabling R&D	66,025	43,123	27,800

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Engineering Research	
■ Reduction in research on superconducting magnets plasma facing components and plasma fueling (following completion of ITER Superconducting Model Coil)..	-7,322
■ Reduction in research on energy extraction, diagnostics, tritium processing, vacuum vessel welding, remote handling, and safety.	-2,731
■ Reduction in design of next step option experiments being considered within U.S. domestic fusion program.	-1,276
■ Increase in Advanced Design Studies	+500
■ Reduction in information technology research	-948
■ Reduction in ITER closeout costs to zero in FY 2000	-3,140
Total, Engineering Research	-14,917

	FY 2000 vs. FY 1999 ($000)
SBIR/STTR	
■ Reduction due to overall reduction in Engineering Research.	-406
Total Funding Change, Enabling R&D	-15,323

Program Direction

Mission Supporting Goals and Objectives

This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress. This subprogram provided the Federal staffing resources and associated funding needed to plan, direct, manage, and administer the highly complex scientific and technical research and development program in fusion energy.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	910	0	0	0	0.0%
Travel	74	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	190	0	0	0	0.0%
Total, Chicago Operations Office	1,174	0	0	0	0.0%
Full Time Equivalents	11	0	0	0	0.0%
Oakland Operations Office					
Salaries and Benefits	184	0	0	0	0.0%
Travel	14	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	2	0	0	0	0.0%
Total, Oakland Operations Office	200	0	0	0	0.0%
Full Time Equivalents	2	0	0	0	0.0%
Headquarters					
Salaries and Benefits	4,001	0	0	0	0.0%
Travel	225	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	700	0	0	0	0.0%
Total, Headquarters	5,526	0	0	0	0.0%
Full Time Equivalents	39	0	0	0	0.0%

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Total Fusion Energy Sciences					
Salaries and Benefits	5,095	0	0	0	0.0%
Travel	313	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	892	0	0	0	0.0%
Total, Program Direction	6,900	0	0	0	0.0%
Full Time Equivalents	52	0	0	0	0.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Salaries and Benefits			
■ Funded staff managing and supporting the Fusion Energy Sciences program.	5,095	0	0
Travel			
■ Provided on-site contractor and facility oversite and participated in major scientific conferences to maintain state-of-the-art scientific and technical expertise.	313	0	0
Support Services			
■ Provided the level of support services needed to provide for the program's mailroom; security; travel services; information technology, infrastructure; and environment, safety and health support..	600	0	0
Other Related Expenses			
■ Provided funds to cover the minimum level of funds to cover hardware/software acquisitions, infrastructure technology upgrades, training, special emphasis programs and the Working Capital Fund..	892	0	0
Total, Program Direction	6,900	0	0

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress.	N/A

Support Services

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Feasibility of Design Considerations . . .	0	0	0	0	0.0%
Economic and Environmental Analysis .	0	0	0	0	0.0%
Test and Evaluation Studies	0	0	0	0	0.0%
Total, Technical Support Services	0	0	0	0	0.0%
Management Support Services					
Management Studies	0	0	0	0	0.0%
Training and Education	5	0	0	0	0.0%
ADP Support	245	0	0	0	0.0%
Administrative Support Services	350	0	0	0	0.0%
Total, Management Support Services	600	0	0	0	0.0%
Total, Support Services	600	0	0	0	0.0%

Other Related Expenses

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	0	0	0	0	0.0%
Working Capital Fund	500	0	0	0	0.0%
Printing and Reproduction	0	0	0	0	0.0%
Rental Space	26	0	0	0	0.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	366	0	0	0	0.0%
Total, Other Related Expenses	892	0	0	0	0.0%

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	1,100	700	800	+100	+14.3%
Capital Equipment	15,295	16,645	10,810	-5,835	-35.1%
Total, Capital Operating Expenses	16,395	17,345	11,610	-5,735	-33.1%

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 1998	FY 1999	FY 2000	Accept- ance Date
DIII-D Upgrade	32,400	18,225	1,550	5,440	5,440	FY 2002
NSTX	21,100	3,570	12,080	5,450	0	FY 1999
NSTX - Neutral Beam	5,950	0	0	3,450	2,500	FY 2000
Total, Major Items of Equipment		21,795	13,630	14,340	7,940	

Science Program Direction

Program Mission

This program provides the Federal staffing and associated funding required to provide overall direction of activities carried out under the following programs in the Office of Science (SC): High Energy Physics, Nuclear Physics, Biological and Environmental Research, Basic Energy Sciences, Fusion Energy Sciences, Computational and Technology Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses. This funding also provides the necessary support to the Director of SC to carry out SC's responsibilities under the Department of Energy (DOE) Organization Act (P.L. 95-91) and as mandated by the Secretary. These responsibilities include providing advice on the status and priorities of the Department's overall research and development programs and on the management of the Department's multipurpose laboratories; developing research and development plans and strategies; and supporting university and science education. This program also provides program-specific staffing resources at the Chicago, Oakland, and Oak Ridge Operations Offices directly involved in executing SC programs.

Program direction has been divided into four categories: salaries and benefits, travel, support services, and other related expenses, the latter including the Working Capital Fund. “Support Services” refers to support services contracts that provide necessary support functions to the Federal staff, such as technical support, computer systems development, travel processing, and mailroom activities. “Other related expenses” refers to other administrative costs of maintaining Federal staff, such as building and facility costs and utilities in the field, information technology expenses, and training. The Working Capital Fund includes centrally provided goods and services at Headquarters, such as supplies, rent and utilities.

Also included in Program Direction are several specific education related activities. For over 50 years, the Department of Energy and its predecessor agencies (Atomic Energy Commission and the Energy Research and Development Administration) has supported science and engineering education programs involving university faculty as well as pre-college teachers and students. The Department has provided support for university students, pre-college teachers and college faculty through hands-on research experiences at the Department’s National Laboratories and research facilities.

The involvement of the Energy Department’s National Laboratories in faculty/student research is perhaps the most distinguishing feature of the agency’s participation over the years in science and engineering education. No other Federal agency has the extensive network of research laboratories and facilities as DOE with its unique physical and human resources. These laboratories and facilities have been key to the Department’s contribution over time to the Nation’s science and engineering education goals.

The funds appropriated for science education will support activities that utilize the Department’s scientific and technical resources to enhance the development of a diverse, well-educated and scientifically literate workforce.

In addition to the science education program in this science program direction budget, other mission oriented education activities are funded within science research programs. Below is a table identifying the programs and the allocation of funds. The funds will allow university faculty and student teams at the undergraduate level to participate on long-term research projects at DOE laboratories. Pre-college science and math teachers will be provided with research appointments to improve their knowledge and skills of scientific discovery and enhance their ability to apply them in a classroom environment. Through these investments, the Department will make major contributions towards fulfilling several national priorities: enhancing the diversity of the technical workforce; supporting systemic reform of undergraduate education; and attracting, retaining, and graduating students in fields of interest to DOE and others in the public and private sectors. The funds will also allow the Department to encourage educators to participate directly in the ongoing science research of its laboratories. By joining teams of researchers, educators will experience directly the cutting-edge development of the Science Laboratories, and will better understand the process of scientific investigation. Funds provided will pay for faculty/student and pre-college teachers' stipends, travel, and housing and will subsidize laboratory scientists' time for this activity.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Basic Energy Sciences	0	0	1,947
Computational Technology Research	0	0	1,947
Biological and Environmental Research	0	0	1,947
High Energy Physics	0	0	2,921
Nuclear Physics	0	0	973
Total	0	0	9,735

Program Goal

To fund the staff and related expenses that are necessary to provide overall management direction of SC's basic and fundamental scientific research programs funded in the Science appropriation; and to enable the Director of SC to serve as the Department's science advisor for formulation and implementation of basic and fundamental research policy.

For science education the goal is to ensure that the Department effectively utilizes and leverages the resources of its laboratory-based system to support its energy, science and math education mission.

Program Objectives

- To develop, direct and administer a complex and broadly diversified program of mission-oriented basic and applied research and development designed to support the development of new and improved energy, environmental and health technologies.
- To manage the design, construction and operation of forefront scientific research facilities for use by the Nation's scientific community, including the Spallation Neutron Source Project.
- To conduct independent technical assessments, peer reviews and evaluations of research proposals, programs and projects.

- To enhance international collaboration to leverage the U.S. investment in research and development.
- To review, analyze and, where appropriate, champion the recommendations of the Office of Science's Federally chartered advisory committees including the Fusion Energy Sciences Advisory Committee, High Energy Physics Advisory Panel, Nuclear Science Advisory Committee, Basic Energy Sciences Advisory Committee, and Biological and Environmental Research Advisory Committee.
- To provide opportunities and effective mechanisms for students and faculty to participate at the Department's laboratories in hands-on research experiences, with a focus on undergraduates.
- To enhance departmental outreach activities in science, technology, engineering and mathematics education at our R&D facilities in order to increase the awareness and understanding of the general public of the Department's science programs.

Performance Measures

- Responsiveness to national science policy and major science initiatives.
- Improvement in environment, safety and health compliance.
- Provision for new and enhanced research facilities and equipment within scope and budget and on schedule.
- Continued improvement in the utilization of staffing, travel and support contractor funds.
- Continuance of improved levels of facility operating time.
- Expansion of international collaborative efforts.
- Cost sharing and leveraging of program resources with other agencies on a one-to-one basis to multiply the program's impact.
- Increase the flow of underrepresented students up to 50 percent into science and math programs/careers achieved.

Significant Accomplishments and Program Shifts

Program Direction

- The Office of Science continues to achieve technical excellence in its programs despite managing one of the largest, most diversified and most complex basic research portfolios in the Federal Government with a relatively small Federal and support contractor staff compared to other programs both within and outside the Department.
- Increased productivity at U.S. scientific research facilities as part of the Scientific Facilities Utilization initiative.

- Concluded the international agreement for U.S. participation in the Large Hadron Collider project. Signatories included the Secretary of Energy and the Director of the National Science Foundation. Execution of the program has begun.
- Initiated operation of the William R. Wiley Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory.
- At Fermilab, complete construction of the C-Zero Experimental Hall within scope and budget, and on schedule (FY 1999 completion); and complete the Main Injector within scope and budget, and on schedule (FY 1999 initial operation).
- Complete the B-factory and its detector at the Stanford Linear Accelerator Center within scope and budget, and on schedule (FY 1999 initial operation).
- Continue construction of the Relativistic Heavy Ion Collider and its detectors at Brookhaven National Laboratory within scope and budget, and on schedule (FY 2000 initial operation).
- Enhance the scientific capabilities for experiments at the Thomas Jefferson National Accelerator Facility (TJNAF) to provide new opportunities for researchers. Three TJNAF experimental halls will be fully operational.
- Carrying out experiments at the Radioactive Ion Beam facility at Oak Ridge National Laboratory.
- Continue pilots in FY 1999 for transfer of management responsibility from Environmental Management to Science for newly generated wastes at the Stanford Linear Accelerator Center (SLAC) and Fermilab.
- Manage the Joint Genome Institute and the Atmospheric Radiation Measurement sites using the National Laboratories as an integrated system.
- Strengthen integrated safety management and infrastructure management at the National Laboratories.
- Operate the state-of-the-art National Energy Research Scientific Computing and Energy Science Network for the benefit of SC and DOE.
- Plan and manage a complex, scientific R&D program to establish the knowledge base needed for an attractive fusion energy science.
- Continue and refine framework of appropriate international arrangements needed to carry out SC programs in a most cost-effective manner.
- Continue to improve environmental, safety and health performance at the Brookhaven National Laboratory through aggressive implementation of the DOE Action Plan for Improved Management of the Laboratory.
- Continue enhancement of neutron science capability at the Los Alamos Neutron Science Center and the High Flux Isotope Reactor at Oak Ridge.
- Continue design and construction of the Neutrinos at the Main Injector (NuMI) project.

- Establishment of the Spallation Neutron Source Project Office at the Oak Ridge Operations Office in FY 2000.
- Implement the Scientific Simulation Initiative to rapidly develop and deploy a national terascale computing infrastructure and apply it to complex civilian science and engineering problems of national importance.

Science Education

- The Science Undergraduate Laboratory Fellowship Program has implemented an innovative, interactive Internet system to receive and process hundreds of student applications for summer and semester research appointments at 11 participating DOE Laboratories. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of the Department's research participation programs.
- Through special recruitment efforts, the Science Undergraduate Laboratory Research Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications represented under represented ethnic groups. About 40 percent of the applications were female, and more than 25 percent were from low-income families. More than 400 summer 1998 appointments were made through the new application process with additional appointments expected in the fall.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Science Program Direction					
Program Direction	37,600	45,300	0	45,300	47,860
Science Education	0	4,500	0	4,500	4,500
Total, Science Program Direction	37,600 [a]	49,800	0	49,800	52,360
Staffing (FTEs)					
Headquarters (FTEs)	220	269	0	269	274
Field (FTEs)	34	49	0	49	51
Total, FTEs	254 [a]	318	0	318	325

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

[a] In FY 1998 $6,900,000 was appropriated for 52 FTEs in the Energy Supply Research and Development Fusion Energy Sciences program now funded in Science Program Direction.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	0	250	250	0	0.0%
Argonne National Laboratory	0	525	525	0	0.0%
Brookhaven National Laboratory	0	525	525	0	0.0%
Fermi Nat'l Accel. Laboratory	0	225	225	0	0.0%
Princeton Plasma Physics Laboratory	0	275	275	0	0.0%
Total, Chicago Operations Office	0	1,800	1,800	0	0.0%
Golden Field Office					
Nat'l Renewable Energy Laboratory	0	225	225	0	0.0%
Oakland Operations Office					
Lawrence Berkeley Nat'l Laboratory	0	475	475	0	0.0%
Stanford Linear Accel. Center	0	225	225	0	0.0%
Total, Oakland Operations Office	0	700	700	0	0.0%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	0	400	400	0	0.0%
Oak Ridge Nat'l Laboratory	0	475	475	0	0.0%
Thomas Jeff. Nat'l Accel. Facility	0	225	225	0	0.0%
Total, Oak Ridge Operations Office	0	1,100	1,100	0	0.0%
Richland Operations Office					
Pacific Northwest Nat'l Laboratory	0	475	475	0	0.0%
All Other Sites	37,600	45,500	48,060	+2,560	+5.6%
Total	37,600	49,800	52,360	+2,560	+5.1%

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is a program-dedicated laboratory (High Energy Physics) located on a 6,000 acre site in Batavia, Illinois. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

National Renewable Energy Laboratory

National Renewable Energy Laboratory is a program-dedicated laboratory (Solar) located on 300 acres in Golden, Colorado. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. Educational activities are in support of the national laboratory participation program which provides hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of Office of Science program and advisory responsibilities. Science Program Direction supports staff in the High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, Computational and Technology Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses programs, including management and technical support staff. This program also supports staff at the Chicago, Oakland, and Oak Ridge Operations Offices directly involved in program execution. The staff includes scientific and technical personnel as well as program support personnel in the areas of budget and finance, general administration, grants and contracts, information resource management, policy review and coordination, infrastructure management, construction management, and environment, safety and health.

The FY 2000 request includes Working Capital Fund resources of $3,285,000 to cover the costs of centrally provided goods and services at Headquarters, such as supplies, rent, and utilities.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	1,949	3,054	3,345	+291	+9.5%
Travel	93	187	190	+3	+1.6%
Support Services	5	198	160	-38	-19.2%
Other Related Expenses	84	124	166	+42	+33.9%
Total, Chicago Operations Office	2,131	3,563	3,861	+298	+8.4%
Full-Time Equivalents	20	32	32	0	0.0%
Oakland Operations Office					
Salaries and Benefits	695	867	889	+22	+2.5%
Travel	20	51	51	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	35	39	39	0	0.0%
Total, Oakland Operations Office	750	957	979	+22	+2.3%
Full-Time Equivalents	6	10	10	0	0.0%

	(dollars in thousands, whole FTEs)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Oak Ridge Operations Office					
Salaries and Benefits	633	634	833	+199	+31.4%
Travel	35	40	70	+30	+75.0%
Support Services	0	0	52	+52	+100.0%
Other Related Expenses	32	68	117	+49	+72.1%
Total, Oak Ridge Operations Office	700	742	1,072	+330	+44.5%
Full-Time Equivalents	8	7	9	+2	+28.6%
Headquarters					
Salaries and Benefits	23,343	28,409	30,180	+1,771	+6.2%
Travel	1,015	1,240	1,420	+180	+14.5%
Support Services	4,690	5,146	5,120	-26	-0.5%
Other Related Expenses	4,971	5,243	5,228	-15	-0.3%
Total, Headquarters	34,019	40,038	41,948	+1,910	+4.8%
Full-Time Equivalents	220	269	274	+5	+1.9%
Total Science					
Salaries and Benefits	26,620	32,964	35,247	+2,283	+6.9%
Travel	1,163	1,518	1,731	+213	+14.0%
Support Services	4,695	5,344	5,332	-12	-0.2%
Other Related Expenses	5,122	5,474	5,550	+76	+1.4%
Total, Science Program Direction	37,600	45,300	47,860	+2,560	+5.7%
Full-Time Equivalents	254	318	325	+7	+2.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Salaries and Benefits			
Staff funded in this decision unit monitor and evaluate over 3,500 grants and contracts at more than 225 institutions, including universities, industry and other government agencies, in addition to monitoring and evaluating the programs at 13 National and single-purpose Laboratories. SC also manages the Department-wide Small Business Innovation Research and Small Business Technology Transfer programs. Our reengineering efforts have eliminated unnecessary and non-value added work from the system where possible. In FY 2000, SC will also support the Spallation Neutron Source Project Office in Oak Ridge and the Scientific Simulation Initiative.	26,620	32,964	35,247
Travel			
The FY 2000 estimate reflects escalation of costs for airfare, lodging, etc. This increase only reflects a two percent increase over FY 1999. Alternatives to travel such as teleconferencing will be utilized when possible.	1,163	1,518	1,731
Support Services			
Provide necessary mailroom, travel services, environment, health and safety support, computer systems development, SBIR program support, security and hardware and software installation, configuration, and maintenance activities. Emphasis in FY 1999 and FY 2000 will be placed on continued implementation of an information architecture for Science to establish integrated business management systems, consistent with the provisions of the Clinger-Cohen Act (Information Technology Management Reform Act) of 1996. This is essential to take work out of the system and to meet workload demands. SC is widely acknowledged as being the most efficient and conservative user of support services contracts in the Department.	4,695	5,344	5,332

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Other Related Expenses			
Acquire computer hardware and software in FY 1999 and FY 2000 necessary to accomplish corporate systems development and networking upgrades. The FY 1999 and FY 2000 estimates include $3,243,000 and $3,285,000, respectively, to cover Headquarters Working Capital Fund charges.	5,122	5,474	5,550
Total, Program Direction	37,600	45,300	47,860

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Salaries and Benefits	
■ Increase of $2,283,000 in salaries and benefits is due to two additional FTE's for the Spallation Neutron Source Project Office in Oak Ridge, five additional FTEs for the Scientific Simulation Initiative, and the impact of cost of living, locality pay, within grades, promotions, lump sum payments, and awards.	+2,283
Travel	
■ Increase of $213,000 in travel provides a partial offset for escalation of travel costs, airfare, lodging, and miscellaneous expenses due to inflation	+213
Support Services	
■ Decrease of $12,000 in support services provides the minimum level of support services needed to provide for SC's needs.	-12
Other Related Expenses	
■ Increase of $76,000 in Other Related Expenses provides the minimum amount of funds to cover hardware/software acquisitions, infrastructure technology upgrades, field training, and the Working Capital Fund.	+76
Total Funding Change, Science Program Direction	+2,560

Support Services

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis . .	1,488	1,488	1,325	-163	-11.0%
Test and Evaluation Studies	0	160	100	-60	-37.5%
Total, Technical Support Services	1,488	1,648	1,425	-223	-13.5%
Management Support Services					
Management Studies	207	207	110	-97	-46.9%
Training and Education	58	63	40	-23	-36.5%
ADP Support	2,282	2,376	2,847	+471	19.8%
Administrative Support Services	660	1,050	910	-140	-13.3%
Total, Management Support Services	3,207	3,696	3,907	+211	5.7%
Total, Support Services	4,695	5,344	5,332	-12	-0.2%

Other Related Expenses

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	60	71	76	+5	7.0%
Working Capital Fund	2,679	3,243	3,285	+42	1.3%
Printing and Reproduction	0	33	11	-22	-66.7%
Rental Space	0	26	0	-26	-100.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	2,383	2,101	2,172	+71	3.4%
Other	0	0	6	+6	+100.0%
Total, Other Related Expenses	5,122	5,474	5,550	+76	1.4%

Science Education

Mission Supporting Goals and Objectives

For over 50 years, the Department of Energy and its predecessor agencies (the Atomic Energy Commission and the Energy Research and Development Administration) has supported science and engineering education programs involving university faculty as well as pre-college teachers and students. The Department has provided support for university students, pre-college teachers and college faculty through hands-on research experiences at the Department's National Laboratories and research facilities.

The involvement of the Energy Department's national laboratories in faculty/student research is perhaps the most distinguishing feature of the agency's participation over the years in science and engineering education. No other Federal agency has the extensive network of research laboratories and facilities as DOE with its unique physical and human resources. These laboratories and facilities have been the key to the Department's contribution over time to the Nation's science and engineering education goals.

As we approach the new century, the Nation continues to face important challenges related to the recruitment and retention into science and engineering of students who have historically been under represented (e.g., women, disabled persons, African Americans, Hispanic Americans and Native Americans) in these fields. Guided by recent reports such as the National Research Council on Undergraduate Education Achievement Trends in Science and Engineering, the Department will continue to design, through the Office of Science, an undergraduate research fellowship program that couples academic study with extensive hands-on research experiences in a variety of DOE national laboratory settings. This program is intended to enhance the likelihood that underrepresented students will successfully complete their undergraduate studies and move on to graduate school. Historically, over two-thirds of undergraduates who have participated in DOE programs such as this have gone on to graduate school in disciplines directly relevant to the DOE science and technology missions.

In addition to the science education program in this science program direction budget, $9,734,000 of other mission oriented education activities are funded within science research programs. Below is a table identifying these programs and the allocation of funds. The funds will allow university faculty and student teams at the undergraduate level to participate on long-term research projects at DOE laboratories. Pre-college science and math teachers will be provided with research appointments to improve their knowledge and skills of scientific discovery and enhance their ability to apply them in a classroom environment. Through these investments, the Department will make major contributions towards fulfilling several national priorities: enhancing the diversity of the technical workforce; supporting systemic reform of undergraduate education; and attracting, retaining, and graduating students in fields of interest to DOE and others in the public and private sectors. The funds will also allow the Department to encourage educators to participate directly in the ongoing science research of its laboratories. By joining teams of researchers, educators will experience directly the cutting-edge development of the Science Laboratories, and will better understand the process of scientific investigation. Funds provided will pay for faculty/student and pre-college teachers' stipends, travel, and housing and will subsidize laboratory scientists' time for this activity.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Basic Energy Sciences	0	0	1,947
Computational Technology Research	0	0	1,947
Biological and Environmental Research	0	0	1,947
High Energy Physics	0	0	2,921
Nuclear Physics	0	0	973
Total	0	0	9,735

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Undergraduate SC Laboratory Fellowship Program	0	3,900	3,900	0	0.0%
National Science Bowl Program	0	400	400	0	0.0%
Albert Einstein Distinguished Educator Fellowship Program	0	200	200	0	0.0%
Total, Science Education	0	4,500	4,500	0	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Undergraduate SC Laboratory Fellowship Program			
The Science Undergraduate Laboratory Research Fellowship Program is a key component of the SC Science Education Program to enable students to focus their research interests on solving current scientific problems and prepare for meeting the challenge of DOE's future energy science mission requirements. The program will also ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry.	0	3,900	3,900

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
National Science Bowl Program In addition, the Office of Science will manage and support the "National Science Bowl" for high school students from across the country. Since its inception, more than 50,000 high school students have participated in this event. The National Science Bowl is a highly publicized academic competition among teams of high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer, and general science. In 1991, DOE developed the National Science Bowl to encourage high school students from across the nation to excel in math and science and to pursue careers in those fields. It provides the students and teachers who have prepared them a forum to receive national recognition for their talent and hard work. We are planning to invest $400,000 into the National Science Bowl to manage both regional and national competitions.	0	400	400
Albert Einstein Distinguished Educator Fellowship Program The Albert Einstein Fellowship Awards for High School Teachers continues to be a strong pillar of the program for bringing real classroom experiences to our education programs and outreach activities. This congressional initiative, established by the Albert Einstein Distinguished Educator Fellowship Act of 1994, has enabled the Department to maintain an enriching relationship with the National Triangle Coalition that serves the Federal Government as the clearinghouse for selecting the teachers. We plan to invest $200,000 in the Einstein Fellowship Awards which will allow us to place teachers at the Department and in the U.S. Congress.	0	200	200
Total, Science Education	0	4,500	4,500

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ No funding changes from FY 1999 to FY 2000 for Science Education.	0
Total Funding Change, Science Education	0